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ACID DEPOSITION AND RELATED AIR POLLUTION ISSUES

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BEFORE THE

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS UNITED STATES SENATE

NINETY-NINTH CONGRESS

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ACID DEPOSITION AND RELATED AIR POLLUTION ISSUES

THURSDAY, JUNE 26, 1986

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
Washington, DC.

The committee met, pursuant to notice, at 10:16 a.m., in room SD–406, Dirksen Senate Office Building, Hon. Robert T. Stafford (chairman of the committee) presiding.

Present: Senators Stafford, Chafee, Symms, Durenberger, Burdick, Mitchell, Baucus, and Lautenberg.

OPENING STATEMENT OF HON. ROBERT T. STAFFORD, U.S. SENATOR FROM THE STATE OF VERMONT

Senator STAFFORD. The Committee on Environment and Public Works will please come to order.

Good morning and welcome to the first of this committee's legislative hearings on the subject of acid rain.

Actually, it is somewhat misleading, I suppose, to characterize this hearing as one which is dealing with legislation. Although six or more acid rain control bills are pending before the committee, we are not dealing with the specifics of those proposals this morning.

Instead, the purpose today is to bring us up to date with developments in the scientific understanding of acid rain over the last 2 years. This knowledge will help determine the content of the legislation which this committee will report later this year.

I hope the audience noticed the absence of any doubt in my voice in making that statement. This committee will report a bill later this year.

It is my intention, hope, and expectation that this committee will report an acid rain bill this year early enough for consideration by the full Senate. In the past, we have encountered some difficulties in reaching the Senate floor.

But I believe that is in the past. I believe we have turned a corner this year on the issue of new legislation to control air pollution in general and acid rain in particular. It is no longer a question of whether we will or will not act, but when, and I think the answer to when is this year, 1986.

So as not to delay that moment of action any longer, I will cease and desist and ask the other members who are present who may have opening statements to make them.

Then we will turn directly to the distinguished witnesses we have here from the scientific community. We are very grateful, I might say, for their presence with this committee this morning.

Going in the order in which members arrived, I am going to recognize Senator Lautenberg, then Senator Chafee, then Senator Baucus.

OPENING STATEMENT OF HON. FRANK R. LAUTENBERG, U.S. SENATOR FROM THE STATE OF NEW JERSEY

Senator LAUTENBERG. Thank you, Mr. Chairman.

I want to thank you and commend you for scheduling this hearing on what is one of the primary environmental problems facing our country and other nations around the world; namely, acid rain.

Dramatizing the problem is the fact that over 100,000 tons of sulfur dioxide pollution is spewed out over our cities, our forests, our rivers and lakes almost every day. It is clear that the people of this country want it to stop.

In the late 1970's, acidified lakes in the Adirondack region began to draw the attention of citizens from across the country. In 1984, the Office of Technology Assessment reported that 9,000 lakes and 117,000 miles of streams are at risk in States east of or bordering the Mississippi.

Scientists are now discovering that the problem extends west to Colorado, California, and to the State of Washington. Few areas, if any, are immune from this acid rain plague.

Red spruce from Maine and North Carolina are on the decline. The Ohio River Valley has experienced damage and death of its white pines. California's white firs and ponderosa pines are also affected. Evidence shows that this forest damage is linked to acid rain related pollutants.

My own State of New Jersey has seen the effects of acid rain and its related pollutants cause decreasing growth and foliage changes in pitch pine and shortleaf pines in the State's pine barrens. The correlation of acidified streams and reduced productivity of pines in the Lebanon State Forest in my State was the first indication on the eastern seaboard that acid rain was damaging our forests. Also in New Jersey's Kittatinny Mountains, three lakes are threatened, acidity levels endanger trout and bass breeding areas.

As will be understood today by our witnesses whom I welcome, the evidence is building on the health effects of air pollutants related to acid rain. Some recent studies indicate that more people die prematurely from airborne sulfides each year than die on our Nation's highways. Evidence suggests that chronic coughing and sputum production are more common in regions with higher sulphur dioxide and particulate pollution, and chronic wheezing may increase with increased ozone concentrations.

Clearly, this evidence underscores the need for Congress to act. As a cosponsor of Chairman Stafford's acid rain bill, S. 2203, I am committed, with the chairman, to addressing the acid rain problem. I look forward to working with the chairman and my other colleagues on the committee in the battle to protect our forests, our lakes, and our health from acid rain.

I welcome the witnesses, Mr. Chairman, particularly Dr. Lioy who is from our State university medical school at Rutgers. I look forward to his testimony and that of the other witnesses.

Senator STAFFORD. Thank you very much, Senator Lautenberg.

Senator Chafee.

OPENING STATEMENT OF HON. JOHN H. CHAFEE, U.S. SENATOR FROM THE STATE OF RHODE ISLAND

Senator CHAFEE. Thank you, Mr. Chairman.

I want to join in commending you for holding these hearings. It has been a while since we have addressed acid rain. The administration doesn't seem to be giving it the concern that we think it should be given, as far as action goes anyway. I think this is one more effort forward on a cause that you have pushed so hard.

I want to join with you on this issue that is so important, as Senator Lautenberg mentioned, not just to our eastern section of the country but now it has turned out to be a nationwide problem.

I hope we can receive, from the witnesses today, some definitive information on what the situation is now and the causes of it. We believe we know the causes. At least, I am convinced we know what the causes are, and I hope we will hear from the witnesses what steps forward we can take.

Thank you.

Senator STAFFORD. Thank you very much, Senator Chafee.

Senator Baucus.

OPENING STATEMENT OF HON. MAX BAUCUS, U.S. SENATOR FROM THE STATE OF MONTANA

Senator BAUCUS. Thank you, Mr. Chairman.

I have a statement I would like to submit for the record.

Senator STAFFORD. Without objection, we will make it part of the record.

Senator BAUCUS. Let me just summarize the statement.

I think you are doing a great job, Mr. Chairman, of aggressively pushing this issue. I am very heartened to hear your statement that this committee definitely will report out a bill this year. It is my firm hope we do more than report out a bill. I don't know that we will, but we should, I think, push as hard as we can and it is my judgment that we possibly can pass a bill this year with your effort and the efforts of others.

It is important to realize this is not the rehashing of an old issue. There are new developments. There is more definite scientific data which show the causal connection between sulphur dioxide emissions and acid rain.

Second, there is more of a political consensus that action is needed. The President himself has indicated that, yes, there is a problem. It is true he still wants some further study, but, nevertheless, statements from the White House do show that the President himself does more firmly understand and more firmly agree that there is a very definite scientific problem here that has to be resolved and that legislation probably is essential.

As has been stated, this is also a new issue in that this is a nationwide problem. It is not only SO_2 emissions that affect the

Northeast but also nitrous oxides which contribute to the problem, and ozone gas also contributes.

Out West, I think it is important to realize that not only sulfur dioxide emissions which are strictly under control now compared to other parts of the country which are part of the problem but also the stationary and the nonstationary nitrous oxide emissions which I think should be addressed as well.

Further, there is a problem with wood smoke. That also is a nationwide problem which probably helps contribute to the problem. I think we have to address wood smoke and perhaps develop a best available control technology over wood smoke emissions.

It is a complicated subject, as we all know, but it is also a subject that is very imminent. It is one that has to be addressed very quickly, and I commend you, Mr. Chairman, for holding this hearing.

[Senator Baucus' written statement follows:]

OPENING STATEMENT OF HON. MAX BAUCUS, U.S. SENATOR FROM THE STATE OF MONTANA

Mr. Chairman, today's hearing begins what I consider to be a new debate over acid rain and air pollution.

Further, I hope that this is a debate we will resolve this Congress.

This committee under your leadership has focused on acid rain year after year reporting bills in both of the last two Congresses.

But each time Congress found itself tied in a "regional knot" unable to set aside parochial differences while it hid behind the pretext that not enough scientific certainty existed to make a decision.

While there are still nay-sayers, even the President who once blamed air pollution on trees has agreed that the problem of acid rain is real—although he continues to call for more research.

SCOPE OF THE PROBLEM

But while Congress and the President "fiddled," our knowledge of the scope and severity of the problem has expanded.

What was once a concern for a few trout in upstate New York is now recognized as an international problem affecting public health, our forests, agricultural productivity and our built environment.

Before we are through, we may find that air pollution will alter worldwide climates in a way that has not existed for over 100,000 years.

EFFECTS ON FORESTS

In Europe alone, nearly 15 million acres of forests have been affected by what Germans call "Waldsterben" or forest death in just five countries: West Germany, Austria, Czechoslovakia, Poland, and Yugoslavia. Other countries in Europe such as East Germany, Hungary, Romania, the Netherlands, Belgium, France, Switzerland, and Sweden have also reported extensive damage.

A similar phenomena is being experienced throughout North America.

Sharply declining growth rates have been found in several species of trees, all beginning about the early 1960s.

Forest decline is well-documented in mountainous areas of eastern Canada, Vermont, New York, New Hampshire, Maine, and south through the Appalachian Mountains to the Carolinas.

Although less complete, there is increasing evidence that the forests of the western states are being impacted.

In my own state of Montana, the winter snowpack in mountainous areas of western Montana has been shown to accumulate acidic pollutants with readings in the pH range of four to five.

Acidic precipitation with a pH value as low as 4.4 has been measured in rain falling in Yellowstone National Park.

While the forest damage has not been as well-documented in the West as in other areas, it is known that many of our mountains in the West lack the ability to neutralize or buffer the acid.

CAUSE OF THE PROBLEM

It has been known for some time that sulfur dioxide, nitrous oxides, and ozone individually have toxic effects on plants.

Injury to vegetation and forest trees by ozone and other photochemical oxidants has been recorded since the early 1940s. Ozone has damaged or killed thousands of Ponderosa and Jeffrey pines in the San Bernardino Mountains east of Los Angeles. A U.S. Forest Service in 1969 found that 1.3 million Ponderosa pines on 250 square miles in the San Bernardino National Forest were stressed or dying.

Ozone, which forms when nitrogen oxides and volatile hydrocarbons react with oxygen in the presence of sunlight, is now accepted as the main gaseous pollutant responsible for crop damage in the U.S. It is estimated that such damage costs about 1-2 billion dollars per year.

COMBINED EFFECTS OF AIR POLLUTANTS

Emerging evidence points to the combined effects of a number of air pollutants acting together.

We can no longer focus all of our attention solely on sulfur dioxide.

Clearly, the combustion of fossil fuels is the single most important source of the air pollutants responsible for damage to forest and aquatic ecosystems.

Significant reductions in emissions of sulfur dioxide, nitrous oxides and hydrocarbons (VOC) will produce beneficial effects on forest and crop production, aquatic systems, human health, visibility, and materials damage.

WHAT IS NEEDED

What is called for is a broad-based approach to pollution control from both stationary and mobile sources.

We cannot retreat from reducing emissions of sulfur dioxide, but we must do much more.

When one considers the findings of a recent study supported by EPA, which shows that a reduction in ambient ozone levels of 25 percent (from 0.12 to 0.08 parts per million hourly maximum) would produce nearly two billion dollars/year in benefits to crops alone, the importance of implementing a comprehensive and defensible air pollution control strategy becomes more urgent.

NEW STAFFORD CONTROL STRATEGY

Mr. Chairman, earlier this year, I cosponsored an aggressive new approach to the problem of acid rain and air pollution control that you introduced.

It is my hope that this committee will move quickly to consider this legislation.

SULFUR DIOXIDE CONTROLS

This legislation would result in a twelve million ton reduction in sulfur dioxide. It has been criticized because it sets a useful life for coal-fired powerplants. I commend you for recognizing the benefits of using clean burning coals which attain an emission rate of 0.7 pound of sulfur dioxide per million British thermal units of heat input or less.

Concern has been expressed that the 0.7 is so restrictive that virtually no coal exists which could meet this standard. This concern is unfounded.

In 1983, EPA estimated that 10-15 percent of the total U.S. reserves could meet this standard.

Using the restrictive Department of Energy Demonstrated Reserve Base (DRB) definition, over 114 million tons of coal reserves with a 0.7 lb. SO_2/million BTUs are known to exist.

If a less restrictive definition of economically recoverable under current conditions is used, this total rises to over 171 million tons of known reserves.

While I commend the chairman for his foresight in recognizing the economic and environmental benefits of using low sulfur coal, it is my hope that we can work together to ensure the "useful life" concept extends for a long enough period of years to make this approach a realistic alternative to acid rain control.

NITROUS OXIDE CONTROLS

The bill's requirement for both additional stationary and mobile nitrous oxide controls is critical to the West.

The West as a region of the country has been both singled out by the Clean Air Act and has been more aggressive in mandating stringent sulfur dioxide controls. Montana and Wyoming have long had the most stringent sulfur dioxide standard in the nation. Yet each is experiencing acid deposition.

It is clear that, if we are to protect Montana's and the West's "Big Sky," we need to control nitrous oxides.

To my way of thinking, mandating that all automobiles meet the standard of what the top 25 percent have demonstrated they can obtain, is both fair and equitable. EPA's own data show that some of the cleanest emitters are full-sized automobiles.

NORTH AMERICAN TREEATY ON AIR

The proposed legislation calls for greater cooperation between all of the countries of North America. With the Nacozari smelter in Mexico on line, the need for enhanced international cooperation becomes increasingly apparent.

WOODSMOKE

In the past, I have advocated increased research to better understand the problems posed by woodsmoke. What was once considered an isolated problem in the Rocky Mountains is now recognized as a serious problem from New England to the Pacific Coast.

A number of states and local communities has adopted legislation to address the problem.

Approaches have varied from outright ban to performance criteria. EPA is currently considering adopting national performance standards.

Recognition of the problem and public policy to address it needs to be built into the Act.

Woodstoves pose a serious health threat that should be controlled through the use of the best available control technology.

CONCLUSION

I look forward to today's hearing and working with you, Mr. Chairman, to see the Clean Air Act reauthorized this year.

Mr. Chairman, I would like to work with you to develop an appropriate legislative framework to address the problem, a problem in Vermont, Montana and throughout the rest of the country.

Senator STAFFORD. Thank you, Senator Baucus.

We are happy to note that Senator Symms has arrived. Senator, do you have any opening statement you would like to make?

OPENING STATEMENT OF HON. STEVE SYMMS, U.S. SENATOR FROM THE STATE OF IDAHO

Senator SYMMS. Thank you, Mr. Chairman.

I am glad we have this distinguished group of scientists here this morning. I would just say in advance of their statements that I hope we can answer the question of what significant portion of our air quality problems they think we should attribute to fossil fuel burning for electrical generation. I think that is a question I would like to have answered. I think it is important that we get some understanding of that before we try to do anything legislatively.

I thank you for holding these hearings. I have a statement for the record, Mr. Chairman.

[Senator Symms' statement follows:]

OPENING STATEMENT OF HON. STEVE SYMMS, U.S. SENATOR FROM THE STATE OF IDAHO

It's appropriate that this distinguished group of scientists be invited here to discuss acid rain. From the testimony before this committee and published material it appears that air quality has deteriorated to some extent and that this deterioration is associated with serious environmental problems. These general statements appear to be established gospel but I'm not sure just how factual they are.

I hope this hearing helps determine what we actually know and what we suspect. Although I realize that this hearing is not designed to deal specifically with S. 2203 I do have questions on this bill that can be appropriately addressed to this panel.

My first question is: Can we, with certainty, attribute a significant portion of our air quality problems to fossil-fuel burning electrical generating equipment?

Other questions?

Has the National Academy of Sciences made any study of the effects of S. 2203 on electrical rates?

Dealing strictly with mobile sources:

As you know, S. 2203 contains provisions to regulate on-highway heavy-duty engines and off-highway engines used in a wide variety of equipment—including logging and mining applications. Has the National Academy of Sciences reviewed these provisions and analyzed their impact on engine manufacturers and their customers?

A 1981 report by the National Research Council (a part of the National Academy of Sciences) determined that the interaction between NO_x, particulates and hydrocarbon emission control is a significant deterrent to achieving simultaneous emission levels.

Does the NAS have any data to show that emission levels in S. 2203 are simultaneously attainable by engines today or likely to be by 1991 given these trade-offs?

Has the Academy analyzed the impact on ambient air quality and the formation of acid rain from off-highway engines?

If the Academy has not studied this question, please indicate why not.

Does the Academy believe that the requirements of S. 2203 dealing with off-highway engines are technologically feasible and cost-effective?

Senator STAFFORD. Thank you very much, Senator.

I would say to our witnesses again how grateful we are for their help as we begin the work of developing a new committee bill.

Dr. Davis, you are first on the list, and I guess both chivalry and the fact that you are first would suggest you be the leadoff witness.

It would be the Chair's intention to hear all four of the witnesses before we go to questions, if that is agreeable.

We would ask, as far as possible, that you try to limit your presentation to 10 minutes. If you have long written statements, we will make them a part of the record in full, but if you could summarize them in 10 minutes each, that would be appreciated.

Dr. Davis.

STATEMENT OF DR. DEVRA LEE DAVIS, NATIONAL RESEARCH COUNCIL, WASHINGTON, DC

Dr. DAVIS. Thank you very much, Senator. It is a pleasure to see you again, and I thank you for the opportunity to hear from the National Research Council about several of its recent studies in the area of air pollution and public health and acid deposition.

As you know, the National Research Council is the research arm of the National Academy of Sciences, and we have established a new board there, the Board on Environmental Studies and Toxicology of which I am now the director. In that context, we are continuing to pursue these areas.

We welcome the opportunity today to discuss with you these recent studies, and I would just call to your attention the fact that we are especially privileged to have with us distinguished members of those committees, all of whom were selected because of their

outstanding contributions to the science involved. They will be speaking first to you about the reports that they authored, and they may also offer opinions of their own on specific questions that you might wish to ask.

I want to briefly mention to you the rationale for the studies reviewed here, although you well know that much of the impetus came from interests such as that which you have consistently expressed through your committee work over a number of years.

In the case of the air pollution epidemiology study, there the focus was on a question that the Environmental Protection Agency asked us now 2½ years ago which really asked, could air pollution epidemiology studies be of any value whatsoever in the development of standards for air pollution?

I should say that the impetus for that question came out of the judgment of some who are no longer at EPA that epidemiology was of limited value and, therefore, there should be no program of epidemiologic studies at EPA and, in fact, as recently as 4 years ago, there was almost no epidemiologic research being conducted on air pollution effects.

The EPA asked the National Research Council specifically to identify whether or not there were physiologic changes and adverse health consequences that could be associated with air pollution in terms of their biological plausibility and, if so, to identify what methods could be used to assess those changes, and, finally, what types of studies could be done and what exposure conditions needed to be assessed to evaluate those.

The primary goal of epidemiologic studies of air pollution is to relate health outcomes in the human population to exposures to air pollution conditions. This sounds very simple at first glance, but it is hardly that. In almost all cases in the diseases we are interested in—such as chronic lung disease and, in some situations, neurologic disease and, in some circumstances, even cancer—are diseases all of which have multiple causes.

So, it is extremely unlikely that we would ever find a disease which is uniquely caused by the mix of air pollutants to which people are exposed. This makes the study quite difficult.

Despite these difficulties, the committee concluded that evidence from controlled human exposures, toxicology, and epidemiology was sufficient to warrant concern that current air pollution produces substantial adverse health effects in some segments of the U.S. population. These effects include a variety of acute respiratory problems as well as an exacerbation of chronic existing diseases in some persons.

The committee therefore recommended that EPA undertake a series of long-term research support on important questions about the epidemiology of air pollution.

I will not go into the details of that report right now except to say to you that the committee felt that there was an important role for epidemiology in standard setting, that they thought that the health effects of concern did require additional attention, and they were particularly concerned about the lack of long-term commitment to research in this area given the importance.

I might offer as a way of introducing as well the acid deposition testimony that we will hear about from Drs. Gibson and Johnson

an analogy from the 19th century on public health and disease. As you may know, in the 19th century, the leading causes of morbidity and mortality were really infectious diseases. These were in fact substantially reduced by the end of the 19th century, although the mechanisms of these diseases were not well understood.

We essentially improved public health by reducing exposures to multiple factors such as improving nutrition, improving sanitation, improving working conditions, providing for cleaner water. Public health improved despite the fact that we didn't understand the basic mechanisms of those diseases.

An analogous situation may exist today where reducing exposures to air pollutants could improve public health and the environment although the mechanisms for the exact causation of these are poorly understood.

In the case of public health, I think it is fair to state that the marginal or relative contribution of reducing air pollution may be very small. Let me make that clear. But the fact is that we all must breathe air. In that sense, the opportunity for an improvement is very great.

I am not going to talk further about the air pollution epidemiology report. As I see that my colleague, Dr. Lioy, has been called out of the room, I am going to first introduce the witnesses on the acid deposition study, Drs. Gibson and Johnson. We will then return to a discussion of the major findings of the air pollution epidemiology report.

I would suggest that we do hold questions until we are finished.

I would add one thing that was of particular concern in the interpretation of trends in air pollution which is a very complicated issue. The committee recognized that there are competing trends here and that for some of the criteria pollutants, perhaps largely in response to the laws that many of you passed, there have been declines in some of these. However, there are other pollutants for which there have been increases, and there are new pollutants such as wood smoke that pose very serious problems for certain areas of the country.

In the great State of Montana, wood smoke is a serious problem at certain times of the year given the inversions in that State. The committee recognized that the trend toward increased use of wood could pose special problems for certain areas of the country.

In the case of radon, the committee also recognized that there is new evidence on the dangers posed by that indoor exposure that occurs there. The committee was particularly interested in some of the newer trends in air pollution which Dr. Lioy will be glad to elaborate on later.

Now, let's turn to the acid deposition report.

Senator STAFFORD. Dr. Gibson, we would be glad to hear from you.

STATEMENT OF DR. JAMES H. GIBSON, COLORADO STATE UNIVERSITY, FORT COLLINS, CO

Dr. GIBSON. Thank you, Mr. Chairman.

My name is Jim Gibson. Professionally, I am a chemist, but I have been involved in the concern over acid deposition since 1978

which actually predates the National Acid Deposition Assessment Program by about 5 years.

Currently, I am responsible for coordination of the combined precipitation chemistry monitoring networks of the National Atmospheric Deposition Program which began in 1978 and the National Acid Precipitation Assessment Program [NAPAP]. As chairman of the National Research Council Committee on Monitoring and Assessment of Trends in Acid Deposition, I wish to discuss with you our report, titled "Acid Deposition: Long-Term Trends."

The work of the committee that I chaired is the latest of several efforts undertaken by the National Research Council since 1981 to summarize what is known about this complex issue of acid deposition or, as most of you refer to it, acid rain. Our committee's particular task was to document to the extent possible whether emissions of air pollutants such as sulfur dioxide, the formation of acidic deposition, the acidification of lakes and streams, the decline in fish populations, and other environmental effects are linked together over space and time.

In other words, are lakes and streams in the eastern United States and southeastern Canada more acidic or less acidic now than they were early in this century before increasing industrialization? Does the pattern of sulfur dioxide emissions in different regions match the pattern of acidic deposition and the acidification of lakes and streams in those same regions?

We found that we could not answer these questions adequately simply by reviewing the available literature. A number of useful and existing data bases had not been created nor analyzed with acidic deposition in mind. Thus, we obtained much of the original data and carried out original analyses which are contained in our report.

Our committee's main conclusion has two main thrusts. One, sulfur emissions which had led to acidic deposition do appear to have caused acidification of many lakes in the northeastern United States. In the limited number of lakes for which fish surveys are available, increased lake acidity has brought with it declines in fish populations.

Second, lake acidification is not a uniform problem. Individual lakes vary widely in their response to acidic deposition. Over the same period of time that many lakes have become acidic, others have become alkaline. In other words, the connection between acidic deposition and environmental damage is real, but it is more variable and complex than many people may have supposed.

We reached this conclusion after reviewing many different kinds of evidence—data on long-term pollutant emission trends, precipitation chemistry, atmospheric visibility, surface water chemistry of dozens of streams and hundreds of lakes in the eastern United States and southeastern Canada, surveys of fish species, and chemical and other data from lake bottom sediments.

To facilitate this analysis, we chose to analyze emissions and environmental response on a regional basis. Each region was treated independently. Thus, our analyses do not specifically account for inter-regional dependencies as these might be affected, for example, by long-range transport.

Historically, sulfur dioxide emissions have been heaviest in the eastern and midwestern United States where industrial activity has been the greatest during this century. The Northeast has experienced a decline in emissions during the past decade. The Southeast, meanwhile, has seen its relatively lower emission levels increase significantly in the past 25 years. These regional emission patterns are related largely to local production and usage of fossil fuels.

To a considerable degree, environmental damage in these regions follows the pattern of emissions. The Northeast, for example, which has had some of the highest emissions of sulfur dioxide also has had the most acidic rain and the greatest deposition of sulfur.

Similarly, it has the largest number of lakes that we could identify as having been acidified. As emissions have declined in the Northeast over the past decade, so have levels of sulfur in rain as well as the acidity and sulfur in some streams.

In the Southeast, precipitation shows escalating levels of acidity and sulfur, reflecting the increase in industrial emissions. There is also some evidence that streams in this region are now showing increased acidification.

In one phase of our analysis, we compared the lake acidity data from the 1920's, 1930's, and 1940's with recent data for several hundred lakes in New Hampshire, New York, and Wisconsin to see if lakes had become more acidic over time. Taking into account differences in chemical analysis techniques used during this period, we found that, on the average, lakes in New York have probably become more acidic. Lakes in New Hampshire however, on the average, experienced no overall change in acidity, with some lakes becoming more acidic and others more alkaline. Those in Wisconsin, on the average, have actually become less acidic since early in this century.

It should be stressed here that these are averages. Even in regions where "on the average" lakes have shown little change, individual lakes have experienced substantial changes, with some becoming more acidic and others more alkaline.

We found the strongest evidence of environmental effects from acidic deposition in studies of the Adirondack lakes in New York. Studies of sediment cores taken from the bottom of currently acidic lakes in the Adirondacks suggest that natural acidification processes causing increases in acidity of one pH unit normally occur only over hundreds or thousands of years. However, some lakes in the Adirondack Mountains have apparently experienced this magnitude of increased acidity over 20 to 40 in the middle of this century.

We based this conclusion partially on some relatively new evidence from fossil records of lake sediments. Fossil remains of microorganisms called diatoms are found frequently in sediment cores. The number and type of diatoms found in a given layer of sediments may be used to infer the acidity of a lake at the time the sediments were deposited.

Of nine Adirondack lakes for which there are both diatom data and concurrent information on measured pH, sediment chemistry, and fish populations, we found that six lakes showed clear signs of relatively recent acidification. Big Moose Lake, for example, has a

diatom inferred pH of 5.8 prior to 1800. Beginning about 1950, the diatom inferred pH dropped markedly to its current level of 4.9. At the same time, the number of fish species in the lake declined from 10 in 1948 to 5 or 6 in 1962.

Our committee did not address the specific reasons for different responses among Adirondack lakes. However, we point out that differences in surrounding soils and watersheds and in the histories of land use practices within watersheds can cause surface waters within a region to respond differently, even when they are receiving equivalent amounts of acidity from atmospheric inputs.

In addition, we note in our report that in areas in New York, for example, some lakes have become more acidic than can be accounted for solely by acidic deposition. Other factors must be responsible. These factors most likely are other human activities such as farming or forestry.

Unfortunately, several issues we attempted to examine remain unresolved. One of these issues is the relative importance of wet acidic deposition versus gaseous and particulate deposition, or so-called dry deposition, of sulfur and nitrogen oxides.

In addition, adequate historical information was not available to permit a study of nitrogen oxides and nitrates which may play a role in both aquatic and terrestrial system stress.

Another unresolved issue is whether forests, especially high elevation red spruce trees, have been adversely affected by acidic deposition. No definitive evidence on forestry effects was available. We believe that air pollution may be one of several contributing causes in the decline of these trees.

These are some highlights of our conclusions. Our committee did not examine what actions, if any, should be taken to alleviate the effects of acidic deposition nor were we able to examine in any detail the relative contribution of nearby and remote sources of air pollution.

In summary, after a detailed review of historical records and other evidence dating from the late 1800's to the present, our committee concluded that acidic deposition has damaged certain lakes in the Northeastern United States. However, we have also found that the extent of acidification is widely variable within this region and even from lake to lake within a similar geographic area, depending on local conditions.

Thank you.

Senator STAFFORD. Thank you very much, Dr. Gibson.

Dr. Johnson, I guess you are next.

STATEMENT OF DR. ARTHUR H. JOHNSON, UNIVERSITY OF PENNSYLVANIA, PHILADELPHIA, PA

Dr. JOHNSON. Thank you, Mr. Chairman.

I would like to take just a moment to introduce myself. I am a soil scientist and a professor at the University of Pennsylvania. I have spent the last decade doing research on atmospheric deposition and elemental cycling in forests. I have been a member of three National Academy panels and committees which have addressed the issues surrounding acid rain, and I was a member of

the Committee on Monitoring and Trends in Acid Deposition which produced one of the reports that we are discussing today.

Delineating the effects of acid deposition and other airborne chemicals on forests has become paramount in the research designed to determine what levels of chemical emissions are environmentally acceptable. Investigations of forest decline in the mountains of the Eastern United States and Germany have been at the forefront over the past 4 or 5 years, because the phenomena are readily visible, they have occurred in areas of relatively high pollutant deposition, and natural causes are not readily apparent.

As a result of the publicity surrounding it and the availability of regional scale data, the Committee on Monitoring and Trends in Acid Deposition studied the evidence available on the relationship between acidic deposition and the decline of red spruce in the northern Appalachian and Adirondack Mountains. The findings are contained in the committee's report, "Acid Deposition, Long-Term Trends."

My remarks fall into the following sequence. First, I will report the conclusions of the committee with regard to acidic deposition as a causal factor in the red spruce decline. Second, I will try to provide the reasoning which I believe justifies the conclusions in light of scientific investigations of cause and effect. Then, I will conclude by giving a summary of the research questions which are now being addressed with respect to the red spruce decline and some of my opinions on how the results of past and ongoing research should be viewed in formulating air pollution control policy.

I have made my remarks brief for this morning's session, but I have included for the record four detailed publications which provide the background for my statements. I request that those publications be made part of the record.

Senator STAFFORD. We will, without objection, by reference make them a part of this hearing record.

[The publication referred to, "Recent and Historic Red Mortality: Evidence of Climatic Influence," "Spruce-Fir Research Plan," "Acid Deposition: Assessing Cause and Effect," and "The Nature and Timing of the Deterioration of Red Spruce in the Northern Appalachian Mountains" have been received and are retained in committee files.]

Dr. JOHNSON. Tree ring data and historical data on stand composition and mortality have given some insight into the changes which have occurred in the populations of red spruce, an important species on the mid and upper slopes of the northern Appalachian and Adirondack Mountains. In 1982, findings of unusual mortality of red spruce on Camels Hump Mountain in Vermont were made public. The concurrent episode of forest decline in Germany and the early German hypotheses that implicated soil acidification and acidic deposition as major factors triggered research and speculation about the role of acidic deposition in the recent change in the high-elevation forests of the Northeast.

Considerable research had been carried out which showed many possible pathways by which acidic substances could adversely affect trees, and information was emerging about the detrimental effects on vegetation of ambient levels of ozone. The data available in 1982 which have been since confirmed suggested that the high elevation

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forests where decline was noted received higher rates of acid and metal deposition than any other extensively forested area in eastern North America.

Thus, the idea that airborne chemicals may participate in the spruce decline gained support. With this background, the committee began its work in 1983.

The data we saw were sufficient to confidently determine that spruce populations had changed in the northern Appalachians with rather substantial mortality noted in some places. The available tree ring evidence and historical reports suggested that the changes in the forest began in the early 1960's or shortly before.

The beginning of the episode of decline coincides with some important climatic anomalies which are generally accepted as being stressful to trees and which are thought by many scientists to be capable of initiating a decline syndrome. A decline syndrome is a disease complex which has biotic and abiotic components and which may act on a population over a period of many years.

The climatic anomalies include a decade of cold winters and the occurrence of an extreme drought in the mid-1960's. Thus, climate stress enters as a potential cause of the spruce decline.

To further complicate the assessment of pollutant impact, any pollutant induced mortality is superimposed on the natural background of mortality which is caused by competition and other natural processes. In addition to these complexities, there is a major gap in the descriptive data which characterize the decline.

While it is known that there are fungal pathogens on some of the declining spruce, there have been no systematic surveys of biotic agents which may play a role, so our understanding of the decline phenomenon must be considered very sketchy. In light of the many unknowns, the conclusion we reached was that the relative importance of competition, climatic and biotic stresses, and acidic deposition and other pollutants could not be adequately evaluated with the available data.

While the package of factors appeared to be complex and not resolvable into its components, we asked if there was enough evidence to conclude that acidic deposition was a likely contributor or, alternatively, if there was enough evidence to rule out acidic deposition and/or other air pollutants as contributing factors. In all components of the trends study, the committee inferred cause and effect if there was spatial and temporal consistency of emissions or acidic deposition rates and a particular environmental change and if there was evidence of a mechanism or a clear chain of changes which led from the deposition of acidic substances to the observed environmental change.

In the case of red spruce, there is no clear evidence of a mechanism linking acid deposition to reduced vigor or mortality, although several possibilities have been proposed as possible and some through future research, may be accepted as having a role.

The information on spatial and temporal consistency between deposition, mortality, and growth reductions is not sufficient to confirm or deny a consistent relationship between deposition and spruce decline.

Data contained in the committee's report and subsequent analyses show that red spruce are adversely affected by warm late

summer temperatures and cold temperatures in early winter. The most recent period of decline began during a time when those unfavorable climatic conditions prevailed and, since the report was finalized, we have documented the occurrence of other periods of severe red spruce decline during times which are climatically unfavorable in that they were marked by cold early winters and warm late summers.

Based on the committee's assessment of the beginning of high rates of sulfur and nitrogen emissions, air pollution could not have been a major factor in the decline of red spruce during the 1870's and 1880's when it was reported that about half of the mature spruce in the Adirondacks died. On the other hand, the summer and winter temperatures of the 1870's were the worst on record for red spruce growth. Thus, major episodes of red spruce mortality can occur in the absence of air pollution and during periods which are climatically unfavorable.

Overall then, because there is no evidence now of mechanisms linking acid deposition to the red spruce decline, and because there is not at present enough data to test for spatial consistency between patterns of deposition and the severity of decline, a cause and effect relationship cannot be inferred. The committee report noted the probable involvement of climate in the decline, and our recent work is consistent with that position.

It is important now to point out that the suggestion of a climatic influence in no way eliminates air pollution as a possible agent involved in the red spruce decline. Indeed, it will not be possible to reconstruct the effects of the climatic events of 25 years ago in such a way as to convincingly demonstrate that natural influences alone caused the mortality.

Some recent studies suggest the possibility of air pollution influence. Greenhouse studies with red spruce seedlings, native soils, and ambient levels of sulfur and nitrogen in mist and simulated rain have suggested that drought stress can be increased by acid deposition, and lead at levels now present in the high elevation soils has been shown to have an inhibitory effect upon red spruce seedling growth.

Many other experiments are underway which will help determine if there are plausible mechanisms which link air pollutants to adverse physiological or biochemical effects in red spruce and many other species. Many of the mechanistic studies are being coordinated through the U.S. EPA and the U.S. Forest Service in the Spruce-Fir Cooperative Research Program. This effort is being funded by the Federal Government, the forest products industry, and coal producers. A research plan for that effort has been submitted for the record.

The last issue I want to address is the next level of research, and I refer to it as the next level because the first 5 or 6 years has been spent documenting recent and rapid changes in the spruce-fir forests, the existence of high levels of pollutant deposition in those forests, the existence of stressful climatic periods, the existence of some types of pathogens in declining spruce trees, and documenting the types of effects that acids, heavy metals, and ozone have on seedlings in controlled environments.

A valid research question has been defined, and there is reason to suspect that airborne chemicals may be involved in a major change in one extensive forest type. There is not at this time reason to believe that airborne chemicals are the cause of those changes. The next level of research is designed to determine the causes of the phenomena we have observed.

The research will continue largely as designed by groups of scientists who were brought together by the Spruce-Fir Research Cooperative. In a series of workshops held in 1985 and 1986, 13 working hypotheses were developed as possible mechanisms leading to the spruce decline. The participants who formulated those lines of research were from all sectors of the forest science community.

The possibilities which will be tested involve airborne chemicals such as heavy metals, acidic substances and ozone, as well as natural factors such as winter temperature conditions, climate change, wind stress, and pathogens.

This approach to pursuing multiple working hypotheses is without question a cumbersome way of trying to get rapid answers to policy related questions about specific pollutants. However, it is necessary to explore the merits of all the rational possibilities before a sound scientific consensus is established.

With regard to the time frame for finding answers, the following point is worth keeping in mind. Only a few years have passed since major changes in the forests have become the focus of concern. It took nearly two decades for a consensus to develop on acidification of surface waters by acid deposition, and there are still some debates on key points. It is extremely unlikely, in my opinion, that a consensus will develop regarding the impact of airborne chemicals on forests in less than 5 years, and it will likely take considerably longer than that.

Based on some of the recent studies of ozone and its subtle effects on plants, it is probably not appropriate to focus only on the easily visible changes in the forests which have come to light. It seems reasonable to broaden the research enough so that the basic interactions of airborne chemicals with physiology and biochemistry of forest species can be well enough understood so that we will know under what conditions we should expect adverse effects on the health and productivity of many types of forests.

All of the above is a rather typical example of the complexity and uncertainty scientists usually talk about when asked for answers to politically sensitive questions when information is incomplete. My personal view, however, is that when the case of acidic deposition is viewed in its entirety, the message is clear. Based on the information available on visibility, surface water quality, fish populations, and elemental cycles, we know that acid deposition causes changes in the environment.

We do not know all of the long-term consequences of those changes. For instance, we do not know the extent to which soils acidify under the influence of acid rain. We do not know to what degree a reduction in sulfur emissions will reverse surface water acidification, and we do not know to what extent the products of fossil fuel consumption can be assimilated by forests before unwanted changes occur. We cannot predict the overall impact of

many decades or centuries of airborne chemical deposition on the complex of processes which regulate terrestrial ecosystems.

If there is to be a showdown on emission controls now, it seems to me that the issue boils down more to one of values than to the information that science can provide on the effects of emissions on forests. Aquatic effects of acid deposition have been demonstrated as have effects of ozone on crops and forest trees. Twenty years passed before we knew that a large, regional-scale change was taking place in a major forest ecosystem.

If we are to wait before controlling emissions, we do so knowing that there are changes in the biosphere caused by those emissions and that we cannot accurately predict the effect that those changes will have on the long-term resilience of natural systems.

Thank you.

Senator STAFFORD. Thank you very much, Dr. Johnson.

Dr. Lioy, we would be very pleased to hear from you.

Senator SYMMS. Mr. Chairman, before Dr. Lioy starts, could I just have 30 seconds?

Senator STAFFORD. Certainly, but I would like to wait for questions.

Senator SYMMS. I have a series of questions and a couple of them deal with mobile point sources, and I apologize to the panel because I can't stay, but I will submit them for the record and we can get them in writing. I have a conflict this morning.

Thank you, Mr. Chairman.

Senator STAFFORD. Certainly, Senator. This would be a good time for me to say that the Chair will reserve to all members who can't be here this morning the right to submit questions in writing to the witnesses, if that is agreeable.

Dr. DAVIS. We will be glad to handle the response, because several members of our committee were unable to be here today and might be able to answer some of those questions.

Senator STAFFORD. Thank you very much.

Dr. Lioy.

STATEMENT OF DR. PAUL J. LIOY, ROBERT WOOD JOHNSON MEDICAL SCHOOL, PISCATAWAY, NJ

Dr. LIOY. Good morning. I wish to thank you all for the opportunity to testify before this august body, and I would like to state for the record my appreciation to the Senator from New Jersey, Senator Lautenberg, for his valuable support in terms of getting environmental research funded in this country. We in the scientific community commend him for it, and personally I commend him for it.

Senator STAFFORD. He should be here to hear that.

Dr. LIOY. I wish to address you this morning initially on the issue of the EPA funded NRC report on the epidemiology of air pollution. The report was developed by a multidisciplinary team of scientists who were put together by the National Research Council.

This was unique in some ways because the NRC initially identified the idea that air pollution epidemiology today is not just done by the epidemiologists. What it requires is a team of people who cross the boundaries of biostatistics, environmental exposure, medi-

cine, toxicology, and epidemiology to focus on the critical issues of air pollution epidemiology and what will be problems which will require resolution over the next 10 to 20 years.

One of the major outcomes of our report was the identification of six areas of interest that we feel are extremely important to the scientific community and, eventually, to the regulatory community.

Number one was the issue of acidic aerosol species or particles, something which is a bit different from acid rain. It is the material that can be inhaled by humans when they are sufficiently small in size and can remain there, depending upon the nature and the place of deposition within the lung.

We also are continually concerned with the ozone problem. Ozone, as you well know, from as recently as Monday, is still a burgeoning issue of our time and has been discussed quite extensively by Lee Thomas in his recent public statements.

We also determined that we should have more work on the pollutants: nitrogen oxides, carbon monoxides, radon, and lead.

In addition to that, there are other issues—and I think this was brought up a little earlier; namely, products of incomplete combustion which relate to the wood smoke.

One of the major outcomes of this report was the fact that we felt that there is a role for epidemiologic research in the resolution of air pollution problems. We feel that not every question can and warrants epidemiologic research. However, if you choose your questions wisely, you should be able to develop studies with a variety of techniques that will be able to address important public health issues in epidemiology.

Another issue which we felt was extremely important was the fact that epidemiologic research requires a consistent funding source. The U.S. Environmental Protection Agency has periodically funded epidemiologic research. However, there needs to be a strong institutionalization of epidemiology within EPA. In fact, it might require some cooperation with the Clean Air Science Advisory Committee of the Science Advisory Board to develop a committee that will help EPA identify goals and research plans for the future. It is a critical issue that sometimes gets swept under the carpet in our need to deal with specific or short-term problems. Obviously, the U.S. Environmental Protection Agency has to deal with fires that crop up rather suddenly, one of which is radon. But radon is also an issue requiring a long-term commitment for research, as well as satisfying the initial goal of mitigation.

I think that the committee felt very strongly that epidemiology, requires a long-term commitment of resources.

Some good examples exist of the commitment to collaboration and multidisciplinary research in epidemiology. This includes the present funding by EPA, even though at minimal levels, of a number of teams throughout the country who have been trying to deal with the issues of ozone nitrogen oxides and acidic sulfur aerosols. These teams include members from NYU Medical Center, Harvard University, myself from Rutgers Medical School—now Robert Wood Johnson Medical School—I was formerly at NYU—the University of Arizona, the University of North Carolina, and Columbia University.

In dealing with the problems of ozone, air pollution epidemiology field studies have produced evidence that suggests that there are—although not clinically significant—health effects at ozone levels near the present standard. Therefore, a minimal margin of safety, if any margin of safety, exists for the general public at current levels. Ozone is also a broad regional issue.

In addition to the above, we have begun to rethink our philosophy or approach toward assessing the magnitude of ozone exposure and the potential health outcomes. There is a suggestion—and I am submitting that as evidence along with a number of other peer review publications—that we may in fact want to change the form of the ozone standard to an 8-hour or 10-hour standard to deal with the question of longer term exposures during the day which is experienced by populations such as children in summer camp or people who exercise outside for longer periods of time.

This has all been derived in part from epidemiologic research as well as support data from toxicological studies and clinical studies that have been done throughout the country.

A further example of the team approach to epidemiologic research is the Harvard Six Cities study where, in recent years, even with the comfounding factors of smoking and indoor air pollution, has demonstrated among the 15,000 children studied health effects associated with particulate mass, sulfur dioxide, and sulfate species.

In fact, one of the most interesting facts that has come to light recently within that study is that the area where they seem to have the most significant effects occurred in eastern Tennessee. In this locale the acidic species seem to be a more dominant fraction of the particulate mass.

So, as we look at research questions associated with particulate matter, we have to address the question of fractionation. When we deal with fractionation, we are dealing with organic species being a dominant component, as well as sulfate species. The sulfate species relate back to the emissions from sources that emit sulfur dioxide.

I would like to close with the fact that we feel very strongly that epidemiology has an important place in the quest for understanding and, eventually, revisions of standards associated with sulfur oxides which are the precursors of acid rain and other important criteria and noncriteria pollutants. With vigorous support for research, we can provide a very valuable input to the decisionmaking process.

Finally, any questions that might be derived from the epidemiologic and toxicological parts of this report should be directed to Dr. Devra Davis because my main areas of expertise are the areas of exposure, characterization, and determining which populations may be present in an environment that are exposed to these species.

Thank you.

Senator STAFFORD. Thank you very much, Dr. Lioy.

While the panel has been testifying, I am pleased to note that several of my colleagues who play key roles on this committee have been able to join us. We, in the Senate, always seem to be split between about three committee hearings at once every morning.

Senator Durenberger, do you have any statement at this point?

OPENING STATEMENT OF HON. DAVE DURENBERGER, U.S. SENATOR FROM THE STATE OF MINNESOTA

Senator DURENBERGER. Mr. Chairman, I wanted first to compliment you for this hearing.

Second, I am not going to say anything about Michael Deaver or Canada or anything political. I am on my way up to the Boundary Waters Canoe Area in about 4 hours, and I think everyone here knows our sensitivity in the State of Minnesota and across the northern and northeastern part of the United States to the acid rain issue.

For the record, I think you all know that I am the author of at least one of the several versions of the approach to resolving the problem.

I remember the trip which members of this committee and some of the staff took to Sweden, Switzerland, and Baden-Wurtemberg in the Black Forest last August. From there I went into Poland to look at this issue. I just want to say, Mr. Chairman, if any of you have the opportunity to watch first hand what the Swedes and the Norwegians have to do to offset the impact of British coal in their lakes, do it.

You would see the shock on the faces of the Swiss and Germans as they watch the rather dramatic impact on the Black Forest and on forestation at high elevations in the Alps which obviously has some relationship to nitrogen oxides and sulfur dioxides in some cases. Go to southwestern Poland and Silesia and see the damage that is being done in a variety of ways from atmospheric pollutants that are being generated in central Europe in a rather indiscriminate fashion. Then share with the Poles the frustration that came from lining up with the United States in some international forum in saying we don't need to do any more work in this area— they thought they were scoring with me, but they weren't— clearly, international solutions are needed both in the area of information and source receptor relations and a lot of those sort of things.

I am really grateful to you and to the other members of this committee who have made us go beyond our parochial interests with regard to atmospheric pollutants to look at the greenhouse effect, as has been done in this committee, look at a variety of issues that are world issues, not just New England or northern Minnesota issues.

So, I compliment you and my colleagues on this committee and the staff of this committee for stimulating all of us to keep reaching out to find the solutions to these problems.

Senator STAFFORD. Than you very much, Senator Durenberger.

Senator Mitchell, do you have a statement you want to put in the record or make?

Senator MITCHELL. I do, Mr. Chairman. Thank you, Mr. Chairman. I was going to defer to Senator Baucus because he has another commitment, but he advises me that he doesn't have to leave at the moment.

Senator STAFFORD. I can say that I am going to yield to Senator Baucus to be the first to ask questions.

Senator MITCHELL. I see. Thank you, Mr. Chairman. I have a brief statement I would like to make,

OPENING STATEMENT OF HON. GEORGE J. MITCHELL, U.S. SENATOR FROM THE STATE OF MAINE

Senator MITCHELL. I am pleased that we have the opportunity to hear from representatives of the National Academy of Sciences about their recent research on the adverse effects of acid rain. We have heard previously from the Environmental Protection Agency and other administration witnesses that we do not know enough about these effects to implement acid rain control measures.

The data which we hear about today, however, confirms my judgment that there is sufficient evidence to warrant an immediate control program similar to the one which I proposed in 1981 which this committee has twice endorsed, most recently, 2 years ago.

While the administration continues to argue that the costs of taking action are too high, the research to date indicates that the cost of not taking action will be too high. The administration continues to insist that everything must be known before anything can be done. But in this, as in so many other areas, if we wait until everything is understood about the problem, we may have bequeathed to the next generation some dead lakes, some dead forests, and the possibility of increased lung dysfunctions.

That is not a legacy of a responsible Congress or of a responsible society. Prudence dictates that we act now in a measured, responsible way to begin to deal with this serious problem.

Mr. Chairman, while the Superfund and other conferences have occupied much of our time, the fact that this hearing is scheduled today indicates that this committee and its chairman are committed to action this year. I commend you for that, Mr. Chairman, and support that effort.

We as a people have waited too long already. We are anxious to begin the work in this Congress to implement finally what is seriously necessary and effective acid rain control programs.

I thank you, Mr. Chairman, and I thank Senator Baucus.

Senator STAFFORD. Thank you very much, Senator Mitchell.

Senator Burdick, do you have any statement at this point?

Senator BURDICK. I do not have a statement, but I will have questions.

Senator STAFFORD. All right. We will get to those shortly.

Might I suggest to my colleagues who are here that we limit ourselves in the first round—there will be further rounds if necessary—to 10 minutes each, if that is agreeable.

Senator Baucus, we will recognize you since you have a commitment on the floor.

Senator BAUCUS. Thank you very much, Mr. Chairman.

I would like to ask the panel generally, and anyone who wishes to can respond, we in this committee a couple of weeks ago heard testimony on global warming. I think it is clear that CO_2, ozone, methane, and other gases that contribute to the global warming trend are also gases that play a part in acid deposition.

During that hearing, however, the scientists who came before us gave us projections. That is, if present emission raters were to continue, if the trend were to continue over a certain number of years, they were able to somewhat confidently predict the number of de-

grees which the temperature would rise and some of the problems that would occur.

I am wondering if any of you have thought about or done any study about or come up with any conclusions which would indicate to us what your projected results will be if present trends do continue or if there is an acceleration of some of these gases which seems to be developing continues given a certain data. Have any of you looked at any of that? If you have, I would like to know it.

Dr. DAVIS. I think by the lack of response, you can probably infer that this is an issue of tremendous complexity and that neither of the two panels or committees that we are discussing today directly addressed any of those questions, Senator.

So, I would be delighted to refer it to other colleagues at the National Academy of Sciences and, in fact, we do have a letter that you signed which several of the members of your committee signed asking for advice from the National Academy on this question. I think that the academy will be getting back to you on that point, but at this point, I don't know if anyone on the panel can answer you.

Senator BAUCUS. I appreciate that. I ask the question because I think it is important for us to know what the potential consequences might be so that we can be in a better position to know what, if anything, we should do.

I realize that that was not the central thrust of your study, but do any of you have any tentative feelings about what the results might be if present emission trends continue?

Dr. GIBSON. I suppose we all have a certain qualitative feeling for that, but I don't think that you can provide a quantitative answer for that as maybe you can in terms of the models that have been developed for global warming.

I would point out that the trends in emissions, for example, in the Northeast, have been on the decline. I am talking about sulfur dioxide now. And that would certainly appear to me to be a positive sign that we are seeing one region of the country at least in which trends are on the decline.

In the Southeast, they are on an increase. Possibly in the West, they will be on an increase. I think that in those regions of the country where one sees increasing emissions of sulfur dioxide, one is going to see increasing effects on surface water. I think that right now our best understanding certainly is with the relationship of sulfur dioxide and surface waters.

As Dr. Johnson has mentioned, this is the one area where we seem to have at least a fair understanding of the role. So, I guess if you are going to continue to increase sulfur dioxide levels, at least in a qualitative sense, I would certainly expect that you are going to continue to see increases in the acidification of sensitive lakes and streams.

Senator BAUCUS. I would ask you, Dr. Gibson, what effect does snow precipitation have compared with rain in dealing with the problem of acid deposition? Is there a significant difference between snow precipitation and nonsnow?

Dr. GIBSON. I think the answer is yes in two ways. I guess I could speak to that with a little more authority in terms of the Western situation. Certainly, snow is generally found to be somewhat clean-

er, if you wish, than rain, so that per given water contents, you introduce less of the species into the system.

Second, snow, particularly in the West, builds up, as you well know, during the winter months. Therefore, it furnishes a pulse to the aquatic systems. In the West, we deal with aquatic systems in particular which have little capacity to buffer, in many cases, little soils, thin soils, granitic type materials. So there is a concern over the pulsing situation that occurs in areas which receive heavy snowpack in the winter.

I think the main difference is in the case of the rate at which the material may enter the system and its opportunity for interacting with the soil is less.

Senator BAUCUS. Would the presence of snow cause a greater problem or less of a problem compared with those parts of the country where most of the precipitation is rain, or is there any difference?

Dr. GIBSON. I guess you would say that there is evidence that in the cases where the pollution levels in snow are sufficiently high, it can cause greater problems in terms of its pulsing in the spring. Therefore, you receive a considerable increase suddenly of certain pollutants. So, under certain circumstances, it can be, yes.

Senator BAUCUS. And, very briefly, could you also differentiate among the current effects, future effects, and the marginal effects of acid precipitation in the West?

Dr. GIBSON. Let's look at the West in terms of the region versus urban area situations. It is obvious in certain urban areas, as in the case with the Los Angeles basin, one is seeing air pollution effects. It is probably not acid precipitation. It is probably more oxides of nitrogen, ozone, more of an oxidant effect.

Excluding that, I think in terms of the general regional question, there is no evidence to date that suggests that we are seeing any impact from acidic deposition. I am speaking primarily of the most sensitive part of the system which are the high elevation alpine lakes.

There has been enough research done. The important results I think we are going to see soon from the Western Lakes Survey which EPA has just finished conducting to suggest that the sensitive systems are the high alpine lakes.

So, to date, I would say that we don't have any evidence that there has been a significant change in the chemistry of these systems. Therefore, we have not seen a significant impact.

It is also true, however, that these are—again based on the Western Lakes Survey information that I have been discussing with some of the people involved with that project—our lakes in the West are probably the most dilute in the world. In other words, they are the most slightly buffered to be found anyplace.

This would suggest that if we permit the increase in sulfur dioxide and nitrogen oxide levels—I think nitrate may play a more important role in the West relatively speaking than it does in the East—that we are in a situation where we may in fact see damage to the West.

I wouldn't want to give you any kind of quantitative answer to that. In other words, there are estimates of how much loading of sulfate a given ecosystem can permit before it becomes impacted.

Those estimates vary too much to relate those to the Western situation, but we certainly are on the borderline in these high elevation areas of receiving nitrogen and sulfur deposition in terms of the potential for problems in the future.

So, I guess my feeling is if we should limit the current emissions in the West to what they are today, we would likely not see a problem. We would allow them to climb significantly, we likely are going to see a problem.

Senator BAUCUS. Thank you, very much.

Thank you, Mr. Chairman.

Senator STAFFORD. Thank you very much, Senator Baucus.

Let me direct a question to any member of the panel who cares to comment, and I will start with an observation.

During the last 2 years, my impression is that there have been important developments in several fields, including health effects, forest effects, soil effects, materials damage, and documentation of acidity trends.

My recollection is that new studies have demonstrated health effects from the following: first, short-term exposures to oxides of sulfur and perhaps sulfate as well; second, short-term exposure to oxides of nitrogen; third, long-term exposure to ozone. In addition, my impression is that Dr. Bates who couldn't be with us today and Dr. Spengler who also was not able to make it, have some population studies indicating that there are health effects from current levels of air pollution.

That is the question, I guess, on which I would invite comment.

Dr. LIOY. I guess I think that comes toward me at this point. Let's see if I can proceed in a logical manner in addressing each one of your points.

As you are aware from my previous comments, we have been able to focus more attention in recent years on critical issues in public health associated with atmospheric air pollution. It is primarily due to two facts, one, that we have gotten better at our ability to identify where exposures take place, better measurements of exposures, and better techniques for identifying specific health outcomes that may be appropriate to the questions that are being asked.

With that in mine, I would say yes, there is a lot of new information that is coming out on each one of these issues.

Why don't I do it in reverse. Dr. Bates and Dr. Spengler have new studies that have shown that there are new effects that are related to both ozone and sulfur species. As I mentioned previously, the Harvard six cities study has shown that within populations being studied on a long-term basis in these six cities, there are effects that are being observed for particulate matter, sulfur dioxide, and sulfate.

The suggestion is that the culprit species in the sulfate issue is acidic sulfur.

Dr. Bates has conducted a study where he has done a large population in Canada. He has a large population in Canada to work with. Fortunately, in Canada, they have a good health reporting system for admissions to hospitals for acute respiratory illness. This is not totally available in the United States which makes it difficult to conduct these studies at the present time.

What he has seen is that during the summer, the increase in acute respiratory illness admissions to hospitals have been related to increases in sulfate species and also atmospheric ozone.

At the present time, because of our concern and also the desire of the scientific community to get closer to these issues, this summer, Dr. Bates, my colleagues from NYU, and myself at Rutgers Medical School are conducting a follow-on study partially supported by the U.S. Environmental Protection Agency and partially funded by the Ontario Ministry of the Environment to look at the question of not only what are the indicator species but is it in fact a dual role between ozone and sulfuric acid.

We are presently this summer doing ozone exposure and sulfuric acid exposure studies in Toronto using the same type of health data base that Dr. Bates used previously. So, maybe we will get closer to the issue at the present time.

The fundamental problem we have had to conducting studies in this country is the fact that we do not have a good data base to work with.

As far as long-term exposure to ozone, that question is cropping up rather significantly at the present time. As I stated, I have papers that have been published that I would like to submit as testimony. We have, through the epidemiologic studies that have been done in recent years, seen that there is a relationship between ozone and decrements of pulmonary function. This is a dose response relationship.

In addition to that, it appears as though there is a duration of exposure to ozone and decrement in function relationship. So, a longer term exposure of ozone can seem to show significant changes in pulmonary function.

These are not clinical at the present time in terms of the fact that they just seem to be decrements in function. However, some of the recent work that we have done has shown that if you have a persistent episode of ozone, there will be the potential for an additional duration during which the pulmonary function of children remains somewhat decreased. It is not dramatic. We are not talking about a 35-percent decrease; we are talking about a 5- or 10-percent decrease in function for children who are exercising outdoors for a number of hours a day which seems to suggest a persistent effect.

As far as long-term exposures, meaning multiyear exposures to ozone, the toxicology has not been done, and long-term epidemiologic studies have not been completed. The suggestion is at the present time through toxicological information that at least if animals are exposed to ozone for a longer period of time, it takes them, after the doses have been removed from the animals, it takes a longer period of time for those animals to recover.

So, the suggestion is that on the biochemical level there is the possibility for longer term effects.

Have I answered each one of your points?

Senator STAFFORD. I think you have covered enough so that I would ask if there is any disagreement or any further observation on the part of other members of the panel.

Dr. LIOY. If you would like more information besides my work, I would be happy to provide that to the committee in any subsequent

inquiries you might make to me. There is a lot of good information that is coming out on these issues at the present time.

Senator STAFFORD. Very well.

Dr. JOHNSON. Mr. Chairman, I would like to make an observation about long-term exposure to ozone with respect to forest trees and croplands.

At the present time, there is a lot of emerging evidence that shows that increasing concentrations of ozone through the ambient range, and that would be about 30 to 80 parts per billion, results in decreasing net photosynthesis in a number of crop and tree species. That means that there is a decrease in productivity with an increase in ozone concentrations through the levels that we are experiencing in much of the Eastern United States at the present time.

At the present time, probably six or eight species have been shown to respond that way, including sugar maple and red oak as well as white pine, important species in some of your States. I think this opens up a very important area of research and it certainly strengthens the idea that regional-scale decreases in forest health might be in progress as a result of poor air quality.

Senator STAFFORD. Thank you. I am reminded of the testimony we had in a hearing last week about ozone in the stratisphere. If ozone in the biosphere is so bad down here, it is too bad we can't move the ozone up to the stratisphere where it is needed.

Is there any further comment on Dr. Lioy's testimony?

[No response.]

If not, let me in my remaining couple of minutes in the first round here go to this one.

There is considerable documented forest damage in Europe, especially Germany and Switzerland, to which Senator Durenberger referred. There are also reports of forest damage in the United States as well as indications that growth rates in several species of trees have dropped markedly.

The Swiss and Germans are reportedly convinced beyond any reasonable doubt that their forest damage is due to air pollution. I gather that the level of certainty or at least consensus at that level does not exist on this side of the Atlantic.

Could any of you comment on whether you are seeing forest damage here which is caused by air pollution? By that, I mean cases where air pollution might have been the straw that broke the camel's back—cases where after drought or disease or climatic stress, air pollution pushed forests over the edge.

Dr. JOHNSON. I guess it is up to me to address that, and I welcome the opportunity.

I think that the end of your statement in which you ask if there are any cases where natural stresses and pollution stresses may have combined to cause disease or injury to the forest is essentially what we are addressing now. We are looking at probably a multiple stress syndrome in red spruce, and we are asking that question.

We can't say at the present time that there are such cases where natural and pollution stress have combined on a regional scale.

If we look to see where air pollution has damaged forests, we can find it around point sources and around smelters. On a larger scale, ozone has been implicated in cases of forest damage, and it is now, I think, generally accepted as an agent which has caused

damage to the mixed pine forests of the San Bernardino Mountains, and the origin of that ozone is at least chemical products which are produced in the Los Angeles basin. And there is considerable evidence that eastern white pine in many areas of its range has been damaged by ozone.

In those cases, there are field observations, experimental studies, and the ability to tie those together.

In some of the other cases that we have seen so far in the Eastern United States with changing growth rates and mortality in spruce, we don't yet have that level of information to be confident.

I would like to make a comment about the forest situation in Switzerland and Germany. As a bit of background, I was the organizer of an exchange with 8 United States and 12 German scientists which, in 1984, took place over a 2-week period where we visited 13 declining sites of conifers in Germany and eastern North America.

We debated possible causes. We tried to find some insights into what the causes might be, but, most of all, we were trying to get a common field experience so that we could compare the kinds of research that we were doing and perhaps learn from each other.

I think that we need to be very careful in trying to equate the changes in the forests that have been observed in Germany and Switzerland with changes in the forest that we have observed here. The most striking thing is that the main symptoms of decline are quite different in the German conifers compared to the conifers that we are seeing in eastern North America. That might be due to different species reacting to the same type of stresses, or it might be due to different factors altogether.

So, while one of the driving forces of our concern about the forests is what is happening in Germany, I think that we should, at least scientifically, treat them independently for a while until we can find some more commonality.

Senator STAFFORD. Thank you very much.

My time is up and I am about to yield to Senator Lautenberg. I will say, not entirely seriously, that the Stafford house in Fairfax County has a fair stand of oak trees around it. We have been living there now for a quarter of a century or a little more, and all of a sudden we have lost several mature but not old oak trees, three of them for no apparent reason. So, I would offer that little stand as a basis for some scientific investigation if anybody had the time and the inclination to do it.

Senator Lautenberg.

Senator LAUTENBERG. Thank you, Mr. Chairman.

I am sorry that I was absent for a little portion. If I ask any member of the panel anything that you have already discussed, please just say so, and I will read the record to get the answer to my question.

Dr. Johnson, your evidence and I respect your skepticism, at least, your unwillingness to link directly the decline in forest productivity and sulfur dioxide emission. As the chairman suggests, the other factors that you bring in you say have effects as well.

I wonder whether or not you would be willing to say that you would rule out either the need for future research or the value of pursuing the sulfur dioxide causal effect on the decline and acidifi-

cation of the forests and lakes, particularly in the Northeast, or in other parts of the United States?

Dr. JOHNSON. No, we certainly can't rule out the possibility that there are adverse effects of acidic substances, sulfur and nitrogen, on some of the phenomena that we have observed. We can't rule it out without experimental evidence.

Many of the things that we are seeing in the forests began quite some time ago, 15, 20, or 30 years ago. Similarly, in Germany, growth rates began to decline in a number of species 15, 20, or 30 years ago.

We are not going to be able to reconstruct the natural conditions of those times in such a way that we can be confident that they are due entirely to natural processes. We must discover some of the fundamental relationships in the ways in which air pollutants may alter the physiology or biochemistry of trees. Then, we can project whether or not those alterations would be severe enough to increase natural stresses.

So, I think we need to continue along those lines.

Senator LAUTENBERG. Would you be willing to make a blanket statement that says that we ought to try to substantially reduce sulfur dioxide emissions across our country? Is it a condition that we ought to worry about? Should we just let it be part of the national research program that says we have problems with air pollution and this is simply one of them?

Dr. JOHNSON. The way I would like to answer that is to make this my personal view, and that is that the long-term effects of air pollution are almost certain to be bad and not good. As a result of that, I think that we know enough about the adverse effects in other sectors of the environment to warrant reduction of sulfur emissions.

Senator LAUTENBERG. The focus here is on acid rain in particular, as you know. We obviously in this committee have a concern. You have heard the chairman state our concern about the general effects of all the elements that create air pollution, ozone, et cetera.

I had the feeling from your testimony that you didn't think that the sulfur dioxide emissions played as significant a role as some of the other factors. I just wanted to, if we can, clear that position up. Is there anything you want to add to my observation?

Dr. JOHNSON. Yes. I think that with respect to the testimony that I gave, the committee focused on a rather narrow issue, and that is the decline of one species. It was very prominent. It has been in the news a lot, and we do have regional-scale data over several States that we could assess. We are interested in regional-scale phenomena for the committee's report.

Therefore, we had only this one narrow aspect to look at.

The resolution of that problem is going to be much like peeling an onion. We start with the obvious factors that are involved or the ones we can discover easily. As we get down, layer by layer, we discover effects of things that we are not yet thinking about.

I think that sulfur does not come forward as one where we can easily see its effects, but perhaps it will later on in the investigations.

Senator LAUTENBERG. We peel the onion, we weep, but we devour the onion. I hope that is not the condition we are going to see with our forests and our lakes.

Dr. GIBSON. Senator.

Senator LAUTENBERG. Yes.

Dr. GIBSON. I just wanted to add I certainly——

Senator LAUTENBERG. Dr. Gibson, before you comment, I notice you said snow is cleaner than rain. Since you come from Colorado and snow is a very important part of the recreational infrastructure there, I assume that it is totally unbiased.

Dr. GIBSON. No, that is not a plug for the State's recreational facilities.

I just wanted to say I thoroughly agree with what Dr. Johnson has said. I would point out, as I guess I touched on earlier, and that is I think if policy today is going to be based on pretty much hard scientific evidence, it would have to be based on the role of sulfur in lake and stream acidification. Unlike the question with forests, we do have a pretty good idea about the role it plays in the surface water acidification.

It definitely plays a role. There is more evidence where we are beginning to think that nitrate also plays a role, but the best evidence existing today is for the role of sulfur.

Dr. LIOY. Senator Lautenberg?

Senator LAUTENBERG. Yes.

Dr. LIOY. Can I redirect the thrust of that question to health effects a little bit?

Senator LAUTENBERG. That is just where I wanted to go. You are from New Jersey, and I am from New Jersey, and we know our State to be a vibrant, energetic, very much alive State. We want to protect the well being of our citizens as we do the rest of the country, but we now have a focus, and I would like to hear you explain to this committee why it is that the whole country ought to be concerned about what happens in New Jersey because we are microcosm of what is going to happen in this country.

Dr. LIOY. Now you are going to bring up an hour's discussion.

Senator LAUTENBERG. No, the chairman will remind me of our time limitations.

Dr. LIOY. Let's see if I can do it generically. First, the area of aerosol and acidic species research as it relates to health effects is an area that needs, I would say, an infusion of research money. The whole question has become an important factor at least identified by the Clean Air Science Advisory Committee of EPA in its recent deliberations and, in fact, there is an addendum to the criteria document in the staff paper of EPA for sulfur oxide which is going through and threading through the amount of information that is available on acidic species related to health.

Obviously, from the review of that data, since I am close to a number of the people who have been on that subcommittee revising it, we need an infusion of money. We obviously have only begun to address the issue of subfractionating particulate matter into its forms in recent years.

First of all, the scientific technology for understanding exposure has only begun to develop. The fact that we find environments

where there are higher acidic aerosol concentrations than we expected was a surprise.

So, I think with that in mind and also the fact that some recent investigations done on mucociliary clearance patterns in humans and in animals have demonstrated that concentrations of 100 micrograms per cubic meter and less have shown alterations in mucociliary clearance. That is sort of the same thing as would occur on tobacco smoking.

So, what we are suggesting is that we need to understand the issue more thoroughly, especially since, as we go further along in our understanding of atmospheric species and want to develop standards which are very appropriate to the issues associated with those species, we may want to refine our particulate matter standard to look at acidic sulfur as being one component. Therefore, the health data base, including epidemiologic research as well as toxicologic research and clinical research, needs to be done thoroughly and consistently so that for the next go around we have the information to make the right decisions.

I can use as a basis for that the information that we have now on ozone. It has only been because there has been a very dramatic increase in the amount of research on ozone, epidemiologically, clinically, and in terms of toxicology, that we have begun to see the light, where we stand now and the fact that we do not have a real true margin of safety for ozone at the present time.

Senator LAUTENBERG. Thank you, Mr. Chairman.

Senator STAFFORD. Thank you, Senator Lautenberg.

Next will be Senator Chafee, to be followed by Senator Mitchell, and then Senator Burdick will be batting clean-up on the first round.

Senator CHAFEE. Thank you, Mr. Chairman.

Dr. Johnson, I thought your statement was an excellent one and extremely interesting. It seemed to say there is not at this time reason to believe that airborne chemicals are the cause of many of these problems. You can't tell, and we need more study.

At the same time, I would like to stress what you said at the last part of your statement, your concluding words:

"Aquatic effects of acid deposition are demonstrated. Effects of ozone on crops and forest trees have been demonstrated.

Twenty years passed before we knew that a large, regional-scale change was taking place in a major forest ecosystem. If we are to wait before controlling emissions, we do so knowing that there are changes in the biosphere caused by the emissions and that we cannot accurately predict the effect these changes will have on the long-term resilience of natural systems.

Now, I concede that there is always room for more study, but I believe, and it seems to me you are saying what I believe, that we do know that acid deposition has deleterious effects, and we better do something about it. Is that a fair interpretation of what you are saying in your concluding words?

Dr. JOHNSON. My concluding words indicate that we have changed natural geochemical cycles, that there are unwanted effects in the biosphere as a result of emissions. My personal preference is that I would like to see emissions controlled to, first of all, try to reverse those effects if they are reversible, and, second, what bothers me is the uncertainty of not being able to project accurate-

ly what the long-term effects of decades or maybe centuries of emissions might mean to the biosphere.

Senator CHAFEE. In other words, we are taking a gamble by not doing anything now. You are saying that there are problems, and as you say in your statement,

> Based on the information available on visibility, surface water quality, fish populations, and elemental cycles, we know that acid deposition causes changes in the environment. We do not know all the long-term consequences of these changes.

That is true, but then you go on to say, I think accurately, that if we are to wait before controlling these, we do so without being able to accurately predict how resilient the natural systems are to resist this constant flow of acid depositions on them.

Is that a fair interpretation?

Dr. JOHNSON. Yes, it is.

Senator CHAFEE. Therefore, doesn't it seem wise that we proceed to try to control these emissions now rather than wait until every bit of evidence is in?

Dr. JOHNSON. My personal opinion is that it is wise to start controlling emissions now. That is a personal preference based on what I have seen and the values that I hold.

I couldn't say that the evidence from the forests would say that we need to control emissions to help the forests. That evidence is not in hand at the present time. But my personal opinion is that it is time that we begin to control emissions.

Senator CHAFEE. To a far greater extent than we have now.

Dr. JOHNSON. Yes.

Senator CHAFEE. Dr. Gibson, in your studies that you made of the lakes in the Adirondacks, you came up with some very interesting observations that in some of those lakes, the acidity had increased substantially. In other of the lakes, the exact reverse had taken place. That is a phenomenon that you can't explain.

Is there any connection with the reduced acidity to perhaps the presence of limestone bordering those lakes? Have you any connections such as that?

Dr. GIBSON. I am going to defer to Dr. Johnson on that question since he has been involved in some of those studies and can probably give you a better answer.

Dr. JOHNSON. We don't understand all of the reasons why a single lake went up or went down. It could be a function of inaccuracy in specific chemical measurements, either the early ones in the 1920's or 1930's or perhaps the later ones. We suspect that it has to do with land use changes in the basins more so than its specific geology or more so than inaccuracy in some of the measurements.

Senator CHAFEE. You mean the land use changes in more intensified farming, disappearance of trees, use of fertilizers?

Dr. JOHNSON. Yes, and we were unable, because of the large area involved, to be able to document those land use changes. All we know is simply the comparisons of early data with later data for about 270 lakes.

Senator CHAFEE. I don't know what my time is, but I am going to poll each of the witnesses on the following question: If you were sitting here on this committee, would you vote to recommend that the

sulfur emissions in the country be drastically curtailed? Dr. Johnson?

Dr. JOHNSON. Do I need to answer that?

Senator CHAFEE. Yes.

Dr. JOHNSON. Yes. My personal view is that, because I am a fisherman, because I spend a lot of time in the Adirondacks, because I am convinced that there are adverse effects on the Adirondack lakes, because we have seen a trend toward acidification of the streams in the southeastern United States—and I think that is a fairly new finding in our study—I think that certainly warrants a reduction in emissions.

Senator CHAFEE. Dr. Gibson.

Dr. GIBSON. I won't repeat everything that Dr. Johnson has said, but I thoroughly agree with him. I think the evidence is adequate. My personal opinion is that we need to, in the eastern United States, reduce the emissions of sulfur and I think we need to consider nitrogen oxide emissions as well.

Senator CHAFEE. I will get back to your question. When you say reduce it in the eastern United States——

Dr. GIBSON. I was going to say and I think we need to at least keep it from rising in the western United States.

Senator CHAFEE. Dr. Davis.

Dr. DAVIS. Let me answer your question with a question.

Senator CHAFEE. No, I asked first.

Dr. DAVIS. Well, all right. Are you concerned about sulfates per se or about the general problem of air pollution? As I have seen several versions of bills prepared by this committee, one of the things that they are moving toward which I fully endorse is an integrated approach to air pollution, recognizing that if, for example, one were to control sulfates, one would also be controlling other things.

For example, Dr. Lioy mentioned fine respiratory particles, those very fine particle which get deeply inhaled into the lung. You will control a lot of things together. I think it is clear that the committees have discussed evidence that supports generally reducing exposure to air pollutants, one of which might be sulfate.

Speaking as an individual and of course not representing the views of the National Research Council, I think that this offers an interesting opportunity for preventive medicine by reducing exposures to many air pollutants, and I would recommend that the committee consider the most effective ways to achieve that.

Senator CHAFEE. Dr. Lioy.

Dr. LIOY. It is hard to say just control emissions for SO_2 and for nitrogen oxides. I think from the perspective of public health, in situations where we are dealing with a possible health outcome, obviously, we need to look to the issue of controlling those factors and those pollutants that are causing the problem.

If we are dealing with sulfur dioxide at peak concentrations, obviously those sources should be controlled. On the more generic issue of sulfate aerosol in the environment, we see that there is a broad regional problem. If you are going to control sulfur oxides for the control of the ecological effects, you will obviously reduce the amount of sulfate in the environment that occurs as an aerosol which are precursors to acid rain.

The magnitude and the extent to which that sulfate remains acidic from the standpoint of health will depend upon how far down wind you are. So, I think from that standpoint, I would say yes. But, again, from a health point of view, we have a little bit more intricate problem we are dealing with at the present time.

Senator CHAFEE. Thank you very much.

Thank you, Mr. Chairman.

Senator STAFFORD. Thank you very much, Senator Chafee.

Senator Mitchell.

Senator MITCHELL. Thank you, Mr. Chairman.

I would like to pursue the line of questioning begun by Senator Chafee. I think it is important for us as policy makers to understand the distinction between the effects that have been observed or not observed in different areas. Aquatic, forest, and health have been the subject here today, and there has been occasional reference to several of them at the same time.

I would like to clarify for the record what the circumstance are, at least my understanding of them.

The National Research Council, as I understand it, was established by the National Academy of Sciences and is a part of that organization. In the Research Council's recent report, "Acid Deposition, Long Term Trends," which is this document I have here, it is stated:

> In conclusion, the report found in eastern North America a causal relationship exists between anthropogenic sources of emissions of SO_2 and presence of sulfate aerosol, reduced visibility, and wet deposition of sulfate and that for benchmark streams and watersheds showing no evidence of dominating internal sources of sulfate, there is a cause and effect relationship between SO_2 emissions and stream sulfate fluxes.

From that, I conclude that there has been an observed effect and a causal relationship established between emissions of sulfur dioxide and acidification of bodies of water in eastern North America. Does any member of the panel disagree with that?

[No response.]

May I infer, then, from the silence that there is agreement on that. So that with respect to effect on water resources, there has been an observed effect and a causal relationship established.

With respect to forest damage, Dr. Johnson, I understand your testimony to be that sulfur dioxide is one of several air pollutants that may be implicated in observed damage; that is, that damage has been observed, but the causal relationship has not yet been established with respect to forest damage to the extent that it has been with respect to aquatic resources and that it may be implicated along with others. Is that a correct conclusion?

Dr. JOHNSON. I would like to express it this way. We have seen changes in the forest that are more rapid than we suspect we should have seen. We have seen changes that we can't explain readily with the information we have simply by natural factors.

We are considering a range of natural factors, anthropogenic constituents, and airborne chemicals including sulfur as possible actors in what we have observed with red spruce in particular. That was the subject of the committee's report.

Senator MITCHELL. I thank you.

Now, with respect to health effects, the Council has, of course, published another study, "Epidemiology and Air Pollution," and I understand, Dr. Davis and Dr. Lioy, your testimony dealt with that and, again, that you have indicated that sulfur dioxide may be one of several pollutants implicated in adverse health effects but the specific causal relationship has not been established with respect to sulfur dioxide at least to the extent that it has been with respect to aquatic resources. Is that a correct conclusion from your testimony?

Dr. LIOY. I believe a better way to phrase it is that in terms of acidic particles, we are not quite sure what the causal relationship is yet. I think there has been a lot of work done on sulfur dioxide per se. We do have a national ambient air quality standard. In fact, it recently was reaffirmed.

But in terms of the acidic particles which are the next step once you go from sulfur dioxide oxidized to a particular form, we need more information. We do have suggestions that it is implicated synergistically with ozone. We do have suggestions, at least from some toxicological studies, that it is implicated in its own right at fairly low levels with possible changes in respiratory clearance.

But I think at the present time, we are at the more infant stage with particulate sulfur species than you are with other ecological effects, primarily because the issue is only beginning to be researched at the present time. This has been recognized by the scientific community, and we would like to go forward. As I stated further, we need to do the research to make sure that this is a cause and effect relationship.

Senator MITCHELL. Then, in summary, the evidence which you as scientists present to us as policymakers is that in the area of water resources, we have observed effect and a specific causal relationship established. In the area of forest damage, we have an observed effect but have not yet established a specific causal relationship, and a similar conclusion may be stated with respect to adverse health effects although there, there are many other factors involved in the effects because you have smoking and indoor air pollution and things of that nature.

Dr. LIOY. Not from the standpoint of sulfur dioxide, from the standpoint of sulfur particles. It is a very critical issue because it remains as a very large component of the fine particle fraction of the mass. We are only beginning to, again, get the information available to us to go after the specific health issues.

So, it is a dual question. Yes, we know a lot about the health effects of SO_2, but we are still grappling with the problem of sulfur particles.

Senator MITCHELL. Thank you. Dr. Davis?

Dr. DAVIS. May I add to that point as someone who is interested in preventive medicine? There are three different lines of evidence that you would have as to the health effects of air pollutants in general. You would have theoretical evidence that is based on models and understandings that we have of the functioning of the human lung. You might have experimental evidence based on animal experiments or clinical trials. And you would have epidemiologic evidence based on surveys of exposed humans.

This report primarily focused on the latter type of evidence; namely, studies in exposed humans. Because of that, we are most limited with respect to those kinds of conclusions because we do not in this country today conduct experiments on large populations of humans knowingly any longer.

Consequently, if you were to rephrase your question and ask about the experimental evidence, there we do have a substantial body of evidence developed by the National Toxicology Program, by experimental studies that have been supported by the Environmental Protection Agency with animals exposing them to levels of pollutants. And there is good reason for some of the pollutants to suspect they would be associated with decrements in lung functioning and with effects on human health.

I should state just the obvious that we are not generally talking at all any longer about deaths in this country associated with air pollution. I am a survivor of the killer smog of Donora of 1948. Fortunately, for this country, those episodes are long gone. They are not long gone from the developing world.

But what we are talking about in the case of the work of Dr. Lioy and Dr. Spengler is evidence that air pollution can cause respiratory infections, and some economists who have worked on the committee have indicated that these cost much money to the country because it results in lost days of work. We are talking about things that affect not necessarily the quantity of life but its quality.

The evidence is suggestive on the part of epidemiology and with animal studies as well that there are effects for certain segments of the population that may be significant, particularly those people with pre-existing diseases or for the young or those at high risk.

Senator MITCHELL. Thank you very much.

Mr. Chairman, if I might——

Senator STAFFORD. The Senator has used 10 minutes.

Senator MITCHELL. Well, I will just conclude by saying that I thank the witnesses. The testimony is just overwhelming in view of the circumstances of the need for some action now.

Senator STAFFORD. Senator, we can have a second round if a rollcall doesn't intervene here.

Senator MITCHELL. Thank you, Mr. Chairman.

Senator STAFFORD. I was planning on it.

Senator Burdick.

Senator BURDICK. Thank you, Mr. Chairman.

We have a much bigger problem that has been talked about here this morning. I think we have a continental problem. If you know anything about the Canadian-American border where I come from, you will know what I am talking about.

I don't want to be too critical of our friendly neighbor to the north, but the facts are they don't have a scrubber on a single powerplant, and they have a smelter at Sudbury 2,000 feet high without controls.

How in the world are we going to answer this problem if we don't have cooperation with Canada? I don't know much about the Mexican situation on the border down there, but I understand we need some cooperation there too.

My question for the panel is, have any efforts been made to bring the interests of the North American continent into a concerted action in this area?

Dr. DAVIS. Let me just say that the academy has had a trilateral commission with the Mexicans and the Canadians and is ready to work with scientists in those countries on the scientific issues involved, but I would suggest respectfully that most of those questions are also heavily policy oriented.

We do face a situation where there are smelters in Mexico now that maybe potentially will contribute to emissions in the West as well as the Sudbury smelter that you mentioned. The academy stands ready to assist if it should be asked to provide such advice. There was a recommendation in the Drew Lewis report for such international cooperation, although we have not yet been asked to provide assistance.

Senator BURDICK. I am not opposed to cleaning up our own country, of course, but when you consider that there are no scrubbers on any of the powerplants in Canada and, as you know, all the powerplants that have been built in my part of the country in the rural areas have had scrubbers installed at a big price to the consumers out there. They have cleaned up very well.

So, you are not going to answer the problem unless you get some cooperation from the neighbors.

Now, if you go up to the North Dakota border, you don't have to have a machine or an instrument to test the pollution. You can see it coming across the border. So, I hope that the State Department or somebody can get a dialog going with our neighbors and have a concerted fight against this dread situation.

Is there anything you people can do to bring that about?

Dr. DAVIS. Senator, as you know, the Academy responds to requests from the Congress. If you would like to make such a request, I am sure that Dr. Press and the heads of the National Research Council would be glad to entertain it, but we do not normally initiate such activities.

I certainly concur with you that it is clear this is an example where pollution knows no boundaries.

Senator BURDICK. Right. I have been trying everything to have somebody initiate it. Thank you.

Senator STAFFORD. Thank you, Senator Burdick.

I would point out two things, I think. One, of course, is that the report that Drew Lewis and Mr. Davis provided the White House was, to our pleasant surprise I will say, finally accepted by the White House which does acknowledge the existence of the problem as a hemispheric problem, and also the fact that in the committee bill which several of us introduced, we do therein require that a treaty with respect to atmospheric contaminants for the entire hemisphere be sought and negotiated.

So, we recognize that we do have a problem both on the Mexican border and on the Canadian border. I would have to say, though, that if the Canadians make good on what they have said they will do, they may get ahead of us in cleaning up the situation in that country. It may be an interesting contest to see who can clean up first.

Senator BURDICK. Well, they better get one scrubber going. I haven't seen one yet.

Senator STAFFORD. Dr. Davis, this isn't really a question but a request for you to repeat a statement I thought you made a few moments ago. You said, I think, current levels of air pollution cause adverse health effects. Am I correct that you did make that statement and could you say which air pollutants are causing the problem?

Dr. DAVIS. Let me defer to Dr. Lioy. He can, I think, answer that in more detail.

Let me read the exact sentence from the committee report which said that they find evidence from controlled studies that "current air pollution still produces substantial adverse health effects in some segments of the U.S. population." The critical issue is what segments and what conditions, and I think that Dr. Lioy can speak to that question.

Dr. LIOY. Obviously, one of the major pollutants that we have to consider is ozone. Over time, there have been some reductions in the ozone concentrations in the United States, but I think, as was stated on Monday by Lee Thomas, there are going to be at least 30 urban areas in the United States that will not reach attainment by 1987.

In addition to that, the health research that has been done on the issue of ozone has suggested that there is little margin of safety with the present standard. That is disturbing.

Second, the studies that have been done by Harvard Six Cities on particulate matter presumably using fine particulate matter, sulfur dioxide, and acidic species as indicators of exposures suggest that there are still health effects occurring at current levels.

Dr. DAVIS. Specifically, there are increased hospital emergency room admissions for asthmatics that log statistically significantly with elevations in the ozone level. That has been demonstrated now in a number of countries. In addition, there is the data on respiratory infections in children and there is some suggestion that this can also be found in the adult population.

Dr. LIOY. Other problems which relate more to indoor air pollution is our currently regulated criteria pollutant, nitrogen dioxide. There are suggestions that the indoor levels of nitrogen dioxide are sufficiently high to cause adverse health effects.

Again, we are dealing with a pollutant that has an outdoor standard, but it seems to be an indoor problem. So, we are dealing again with where the pollutant is as well as the type of pollutant involved.

Senator STAFFORD. All right. I certainly am grateful to you all. If we are to go further in reducing ozone in this country, are we not facing the necessity for a cleaner exhaust from the Nation's automobiles, trucks, and buses?

Dr. LIOY. I am not an expert on emissions and what forms of emission reduction will be necessary, but I think what has got to come about is a very vigorous program through EPA to ensure that the types of emission reductions that are proposed will be adequate to address the problem.

Ozone is a regional problem. Therefore, the generic issues are how do we get the most reductions in hydrocarbons at the present

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time and effectively deal with reducing ozone. If you do it on a case-by-case basis, and considering the fact that ozone has no boundaries, it may be extremely difficult to have a significant impact on ozone in many large cities if in fact it isn't done on a regional basis.

Therefore, it requires, I think, a complex strategy which, when implemented, should help us achieve compliance.

Senator STAFFORD. All right. Well, once again to all four of you, I am very grateful that you were willing to come and counsel with us this morning. We recognize we need all the help and advice from experts we can get. We recognize that we have a considerable task ahead of us. Thank you for helping us get on the way.

Dr. DAVIS. Thank you.

Senator STAFFORD. The committee is adjourned.

[Whereupon, at 12:14 p.m., the committee adjourned, to reconvene at the call of the Chair.]

[Statements submitted for the record follow:]

STATEMENT OF

DR. JAMES H. GIBSON
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BEFORE THE

SENATE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

JUNE 26, 1986

Mr. Chairman and Members of the Committee: My name is James Gibson. I am responsible for coordination of the combined precipitation chemistry monitoring networks of NADP and the National Acid Precipitation Assessment Program (NAPAP). As chairman of the National Research Council Committee on Monitoring and Assessment of Trends in Acid Deposition, I wish to discuss with you our report titled "Acid Deposition: Long Term Trends." A copy of the summary of the findings is submitted with my statement for the record.

The work of the committee that I chaired is the latest of several efforts undertaken by the National Research Council since 1981 to summarize what is known about the complex phenomenon of acidic deposition or "acid rain" and to correct many of the misunderstandings surrounding it. Our committee's particular task was to document to the extent possible whether emissions of air pollutants such as sulfur dioxide, the formation of acidic deposition (acid rain), the acidification of lakes and streams, the declines in fish populations, and other environmental effects are linked together over time and space. Are lakes and streams in the eastern United States and southeastern Canada more acidic or less acidic now than they were early in this century before increasing industrialization? Does the pattern of sulfur dioxide emissions in different regions match the pattern of acidic deposition and acidification of lakes and streams in those same regions?

We found that we could not answer these questions adequately simply by reviewing the available scientific literature. A number of useful, existing data bases had not been

created nor analyzed with acidic deposition in mind. Thus individual committee members, with the help of consultants and colleagues, obtained much of the original data and carried out the original analyses which are contained in our report.

Our committee's main conclusion has two main thrusts: (1) First, sulfur emissions which have led to acidic deposition do appear to have caused acidification of many lakes in the northeastern United States. In the limited number of lakes for which fish surveys are available, increased lake acidity has brought with it declines in fish populations. (2) Second, lake acidification is not a uniform problem. Individual lakes vary widely in their responses to acidic deposition. Over the same time period that many lakes have become acidic, others have become more alkaline. In other words, the connection between acidic deposition and environmental damage is real, but it is more variable and complex than many people have supposed.

We reached this conclusion after reviewing many different kinds of evidence: data on long-term pollutant emissions trends, precipitation chemistry, atmospheric visibility, surface water chemistry of dozens of streams and hundreds of lakes in the eastern United States and southeastern Canada, surveys of fish species, and chemical and other data from lake-bottom sediments.

To establish cause and effect between pollutant emissions and environmental damage, it is necessary to demonstrate at least two of three criteria. The first of these is consistency. Do the variables involved change in a consistent way for each set of data? The second is responsiveness. Can it be shown experimentally that a change in one variable produces a change in another variable each time? The third is mechanism. Can a step-by-step pathway be demonstrated from the alleged cause to the observed effects? While we mention some controlled studies of responsiveness in our report, our conclusion that acid deposition has caused environmental damage is based in large part on showing that there is a consistent spatial or temporal relationship and that mechanisms for that relationship are known.

To determine the consistency between spatial and temporal emissions of sulfur dioxide and acidity, alkalinity, and

levels of sulfur in lakes and streams, the committee compared emissions data with water chemistry measurements made at 32 so-called "bench mark" streams and over 1,000 lakes in the midwestern and northeastern U.S. and in southeastern Canada. To facilitate this analysis, we chose to analyze emissions and environmental responses on a regional basis. Each region was treated independently; thus, our analyses do not specifically account for interregional dependencies as these might be affected, for example, by long-range transport.

Historically, sulfur dioxide emissions have been heaviest in the eastern and midwestern U.S., where industrial activity has been greatest during most of this century. The Northeast has experienced a decline in emissions during the past decade; the Southeast, meanwhile, has seen its relatively lower emission levels increase significantly in the past 25 years. These regional emissions patterns are related largely to local production and usage of fossil fuels.

To a considerable degree, environmental damage in these regions follows the pattern of emissions. The Northeast, for example, which has had some of the highest emissions of sulfur dioxide, also has had the most acidic rain and deposition of sulfur. Similarly, it has the largest number of lakes that we could identify as having been acidified. As emissions have declined in the Northeast over the past decade, so have levels of sulfur in rain as well as the acidity and sulfur in some streams.

In the Southeast, precipitation shows escalating levels of acidity and sulfur, reflecting the increase in industrial emissions. There is also some evidence that streams in the region are now showing increased acidification.

In one phase of our analysis, we compared lake acidity data from the 1920s, 1930s, and 1940s with recent data for several hundred lakes in New Hampshire, New York, and Wisconsin to see if the lakes had become more acidic over time. Taking into account differences in chemical analysis techniques used during this period, we found that, on average, lakes in New York have probably become more acidic. Lakes in New Hampshire have, on average, experienced no overall change in acidity, with some lakes becoming more acidic and

others more alkaline. Those in Wisconsin, on the average, have actually become less acidic since early in this century.

It should be stressed here that these are averages. Even in regions where, "on average", lakes showed little change, individual lakes have experienced substantial changes, with some becoming more acidic and others more alkaline.

We found the strongest evidence of environmental effects from acidic deposition in studies of the Adirondack lakes in New York. Studies of sediment cores taken from the bottom of currently acidic lakes in the Adirondacks suggest that natural acidification processes causing increases in acidity of one pH unit normally occur only over hundreds or thousands of years. However, some lakes in the Adirondack Mountains have apparently experienced this magnitude of increased acidity over 20 to 40 years in the middle of this century.

We based this conclusion partially on some relatively new evidence from the fossil records of lake sediments. Fossil remains of microorganisms called diatoms are found frequently in sediment cores. The number and type of diatoms found in a given layer of sediments may be used to infer the acidity of a lake at the time the sediments were deposited. Of nine Adirondack lakes for which there are both diatom data and concurrent information on measured pH, sediment chemistry, and fish populations, we found that six lakes showed clear signs of relatively recent acidification. Big Moose Lake, for example, had a diatom-inferred pH of 5.8 prior to 1800. Beginning about 1950, the diatom-inferred pH dropped markedly to its current level of 4.9. At the same time, the number of fish species in the lake declined from 10 in 1948 to five or six in 1962. In contrast, diatom evidence from Lake Sagamore in the Adirondacks shows an insignificant change in pH -- from 6.3 prior to 1800 to 6.1 currently. The sediment chemistry and lack of major changes in the number of fish species in the lake confirms that no significant acidification has taken place.

Our committee did not address the specific reasons for different responses among Adirondack lakes. However, we do point out that differences in the surrounding soils and watersheds and in the histories of land-use practices within

watersheds can cause surface waters in a region to respond differently, even when they are receiving equivalent amounts of acidity from atmospheric inputs. In addition, we note in our report that in areas in New York, for example, some lakes have become more acidic than can be accounted for solely by acidic deposition. Other factors must be responsible. These factors most likely are other human activities such as farming or forestry.

Unfortunately, several issues we attempted to examine remain unresolved. One of these issues is the relative importance of wet acidic deposition versus gaseous and particle deposition, or so-called dry deposition, of sulfur or nitrogen oxides. In addition, adequate historical information was not available to permit a study of nitrogen oxides and nitrates which may play a major role in both aquatic and terrestrial system stress. Another unresolved issue is whether forests -- especially high elevation red spruce trees -- have been adversely affected by acidic deposition. No definitive evidence on forestry effects was available. We believe that air pollution may be one of several contributing causes of declines in these trees.

These are some of the highlights of our conclusions. Our committee did not examine what actions, if any, should be taken to alleviate the effects of acidic deposition. Nor were we able to examine in any detail the relative contributions of nearby and remote sources of air pollution.

In summary, after a detailed review of historical records and other evidence dating from the late 1800s to the present, our committee concluded that acidic deposition has damaged certain lakes in the northeastern United States. However, we have also found that the extent of acidification is widely variable within this region and even from lake to lake within smaller geographic areas depending on local conditions.

Testimony Before the U.S. Senate Committee on the Environment and Public Works

Arthur H. Johnson
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June 26, 1986

Delineating the effects of acid deposition and other airborne chemicals on forests has become paramount in the research designed to determine what levels of chemical emissions are environmentally acceptable. Investigations of forest decline in the mountains of the eastern U.S. and Germany have been at the forefront over the past four or five years because the phenomena are readily visible, they have occurred in areas of relatively high pollutant deposition, and natural causes are not readily apparent. As a result of the publicity surrounding it, and the availability of regional-scale data, the Committee on Monitoring and Trends in Acid Deposition studied the evidence available on the decline of red spruce on the slopes of the northern Appalachians and Adirondack Mountains. The findings are contained in the Committee's report, "Acid Deposition, Long Term Trends". My remarks fall into the following sequence. First, I will report the conclusions of the Committee with regard to acid deposition as a causal factor in the red spruce decline. Second, I will provide the reasoning which I believe justifies the conclusions in light of scientific investigations of cause-effect relationships. I conclude by giving a summary of the research questions being addressed, and my opinions on how the results of the past and ongoing research should be viewed in formulating air pollution control policy.

I have made my remarks brief for this morning's session, but have included for the record four detailed publications which provide the background for my statements. I request that those publications be made part of the record.

Tree-ring data and historical data on stand composition and mortality have given some insight into the changes which have occurred in the populations of red spruce, an important species on the mid and upper slopes of the northern Appalachian and Adirondack Mountains. In 1982, findings of unusual mortality of red spruce on Camels Hump Mountain in Vermont were made public. The concurrent episode of forest decline in Germany and the early German hypotheses that implicated soil acidification and acid deposition as major factors triggered research and speculation about the role of acid deposition in the recent change in the high elevation forests of the Northeast. Considerable research had been carried out which showed many possible pathways by which acidic substances could adversely affect trees, and information was emerging about the detrimental effects on vegetation of ambient levels of ozone. The data available in 1982 suggested that the high elevation forests where decline was noted received higher rates of acid and metal deposition than any other extensive forest type in North America. Thus the idea that airborne chemicals may participate in the spruce decline gained support. With this background, the committee began its work in 1983.

The data were sufficient to confidently determine that spruce populations had changed in the northern Appalachians and in the Adirondacks, with rather substantial mortality noted in some places. The available tree ring evidence and historical reports suggested that the

changes in the forest began in the early 1960's or shortly before. The beginning of the episode of decline coincides with some important climatic anomalies which are generally accepted as being stressful to trees, and which are thought by many scientists to be capable of initiating a decline syndrome--a disease complex which has biotic and abiotic components and which may act on a population over a period of many years. The climatic anomalies include a decade of cold winters, and the occurrence of an extreme drought in the mid-1960's. Thus climate stress enters as a potential cause of the spruce decline. To further complicate the assessment of pollutant impact, any pollutant-induced mortality is superimposed on the natural background of mortality which is caused by competition and other natural processes. In addition to these complexities, there is a major gap in the descriptive data which characterize the decline. While it is known that there are fungal pathogens on some of the declining spruce, there have been no systematic surveys of biotic agents which may play a role, so our understanding of the decline phenomenon must be considered very sketchy. In light of the many unknowns, the conclusion we reached was that the roles of competition, climatic and biotic stresses, and acid deposition and other pollutants could not be adequately evaluated with the available data.

While the package of factors appeared to be complex and not resolvable into its components, we asked if there was enough evidence to conclude that acid deposition was a likely contributor, or alternatively, if there was enough evidence to rule out acid deposition and/or other air pollutants as contributing factors. In all components of the "Trends" study, the Committee inferred cause and effect if there was spatial and temporal consistency of emissions or acid deposition rates and a particular

environmental change and if there was evidence of a mechanism or a clear chain of changes which led from the deposition of acidic substances to the observed environmental change. In the case of red spruce, there is no clear evidence of a mechanism linking acid deposition to reduced vigor or mortality, although several possibilities have been proposed as possible and may, through future research, be accepted as having a role.

The information on spatial and temporal consistency between deposition, mortality and growth reductions is not sufficient to confirm or deny a consistent relationship between deposition and spruce decline. The decline of spruce is most severe at high elevation where deposition is projected to be greatest, but other natural stress factors increase with increasing elevation as well. Growth reductions in spruce have been found in low elevation areas which do not receive as much acid deposition as the higher elevation sites, and the departure from the long-term response of annual growth to climate which characterizes decline at high elevation also occurs at low elevation.

Data contained in the Committee's report and subsequent analyses show that red spruce are adversely affected by warm late summer temperatures and cold temperatures in early winter. The most recent period of decline began during a time when those unfavorable climatic conditions prevailed, and since the report was finalized, we have documented the occurrence of other periods of severe red spruce decline during times which were climatically unfavorable in that they were marked by cold early winters and warm late summers.

Based on the Committee's assessment of the beginning of high rates of S and N emissions, air pollution could not have been a factor in the major

decline of red spruce in the 1870's and 1880's when it was reported that about half of the mature spruce in the Adirondacks died. On the other hand, the summer and winter temperatures of the 1870's were the worst on record for red spruce growth. Thus, major episodes of red spruce mortality can occur in the absence of air pollution and during periods which are climatically unfavorable.

Overall, then, because there is no evidence now of mechanisms linking acid deposition to the red spruce decline, and because there is not at present enough data to test for spatial consistency between patterns of deposition and the severity of decline, a cause and effect relationship cannot be inferred. The Committee report noted the probable involvement of climate in the decline, and our recent work is consistent with that position.

It is important to point out that the suggestion of a climatic component in no way eliminates air pollution as a possible agent involved in the red spruce decline. It will not be possible to reconstruct the effects of climatic events of 25 years ago in such a way as to convincingly demonstrate that natural influences alone caused the mortality. Recent greenhouse studies with red spruce seedlings, native soils and ambient levels of S and N in mist and simulated rain have suggested that drought stress can be increased by acid deposition, and Pb at levels now present in high-elevation soils has had an inhibitory effect on red spruce seedling growth. Many other experiments are underway which will help determine if there are plausible mechanisms which link air pollutants to adverse physiological or biochemical effects in red spruce and many other species. Many of the mechanistic studies are being coordinated through the U.S. EPA

and the U.S. Forest Service in the Spruce-Fir Cooperative Research Program. A research plan for that effort has been submitted for the record.

The last issue I want to address is the next level of research. I refer to it as the next level because the first five or 6 years has been spent documenting recent and rapid changes in the spruce-fir forests, the existence of high levels of pollutant deposition in those forests, the existence of stressful climatic periods, the existence of some types of pathogens in declining spruce trees, and documenting the types of effects that acids, heavy metals and ozone have on seedlings in controlled environments. A valid research question has been defined, and there is reason to suspect that airborne chemicals may be involved in a major change in one extensive forest type. There is not at this time reason to believe that airborne chemicals are the cause. The next level of research is designed to determine the cause of the phenomena we have observed.

The research will continue largely as designed by groups of scientists who were brought together by the Spruce-Fir Research Cooperative. At a series of workshops held in 1985 and 1986, 13 working hypotheses were developed as possible mechanisms leading to the spruce decline. The participants who formulated those lines of research were from all sectors of the forest science community. The possibilities listed involve airborne chemicals such as heavy metals, acidic substances, and ozone, as well as natural factors such as cold winters, climate change, wind stress, and pathogens. This approach of pursuing multiple working hypotheses is without question a cumbersome way of trying to get rapid answers to policy-related questions about effects of specific pollutants. Unfortunately it is necessary to explore the merits of all of the rational possibilities before a sound scientific consensus is established. The most rational

approach is to first, characterize the natural components of the decline and then test to see if pollutants alter the trees in a way which increases the natural stresses.

If legislation is to await a consensus on the issue of acid deposition effects on forests, the following point is worth keeping in mind: only a few years have passed since major changes in the forest have become a focus of concern. It took more than a decade for a consensus to develop on the acidification of surface waters by acid deposition, and there are still debates on some key points. It is extremely unlikely that a consensus will develop regarding the impact of airborne chemicals on forests in less than five years and it will likely take longer than that.

Based on some of the recent studies of ozone and its subtle effects, it is probably not appropriate to focus only on the easily visible changes in the forest which have come to light, but it seems reasonable to broaden the research enough so that the basic interactions of airborne chemicals with the physiology and biochemistry of forest species can be well-enough understood so that we will know under what conditions we should expect adverse effects on the health and productivity of many types of forests. This would involve an extensive, long-term research effort.

All of the above is a rather typical example of the complexity and uncertainty scientists usually talk about when asked for answers to politically sensitive questions when information is incomplete. It seems to me, however, that when the case of acid deposition is viewed in its entirety, the message is clear. Based on the information available on visibility, surface water quality, fish populations, and elemental cycles, we know that acid deposition causes changes in the environment. We do not

know all of the long-term consequences of those changes. For instance, we do not know the extent to which soils acidify under the influence of acid rain. We do not know to what degree a reduction in sulfur emissions will reverse surface water acidification, and we do not know to what extent the products of fossil fuel consumption can be assimilated by forests before unwanted changes occur. We cannot predict the overall impact of many decades or centuries of airborne chemical deposition on the complex of processes which regulate terrestrial ecosystems. If there is to be a showdown on emission controls now, it seems to me that the issue boils down to one of values more than to information that science can provide now on the effects of emissions on forests. Aquatic effects of acid deposition are demonstrated, Effects of ozone on crops and forest trees have been demonstrated. Twenty years passed before we knew that a large, regional-scale change was taking place in a major forest ecosystem. If we are to wait before controlling emissions, we do so knowing that there are changes in the biosphere caused by the emissions, and that we cannot accurately predict the effect those changes will have on the long-term resilience of natural systems.